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ARTILLERY FIRING ACCURACIES FOR PROJECT PASS USING THE ARTY/GWC--ETC(U)
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ARTILLERY FIRING ACCURACIES FOR PROJECT PASS USING THE ARTY/GWC METHOD

By: R. L. MANCUSO

Prepared for:

ATMOSPHERIC SCIENCES LABORATORY
U.S. ARMY ELECTRONICS COMMAND
WHITE SANDS MISSILE RANGE, NEW MEXICO 88002

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STANFORD RESEARCH INSTITUTE
Menlo Park, California 94025 · U.S.A.

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Approved by:

R.T.H. COLLIS, *Director*
Atmospheric Sciences Laboratory

RAY L. LEADABRAND, *Executive Director*
Electronics and Radio Sciences Division

332 500

ABSTRACT

The ARTY/GWC method for providing meteorological messages for artillery firings was tested in this study. In this method, Global Weather Central (GWC) 18-hour prognostic fields are updated continuously using Army Corps upper-air soundings. This establishes a prognostic data base from which meteorological messages may be extracted when required. The testing of the method consisted of comparing actual and simulated cannon firings, using data from the artillery field experiments that were carried out at White Sands Missile Range in November and December of 1974. The accuracies of the simulated artillery firings using the ARTY/GWC method were not significantly better than those obtained using established techniques. However, improved accuracies with this method should be possible when prognostic products become available that are generated by numerical models designed to treat regions of limited size in more detail, particularly with regard to the boundary layer and mountainous terrain.

CONTENTS

ILLUSTRATIONS

ABBREVIATIONS

AAR	Artillery Applications Routine
ARMDAT	Army Data
ARTY	Artillery
ARTY/GWC	Artillery/Global Weather Central
AWS	Air Weather Service
BRLBTS	Ballistic Research Laboratory Ballistic Trajectory Simulation
GMT	Greenwich Mean Time
GWC	Global Weather Central
GWCDAT	Global Weather Central Data
MET	Meteorological
PASS	Prototype Artillery Subsystem
PDRR	Prognostic Data Reanalysis Routine
PE	Probable Error
WSMR	White Sands Missile Range

I INTRODUCTION

The success of artillery cannon firings depends significantly on the accuracy of meteorological (MET) data. For the purpose of improving on ballistic MET messages and artillery accuracies, the U.S. Army carried out the Prototype Artillery Subsystem (PASS) field experiments in late 1974 at White Sands Missile Range (Barnett, 1976). These experiments consisted of Howitzer firings concurrent with upper-air soundings at ten MET stations (Figure 1).

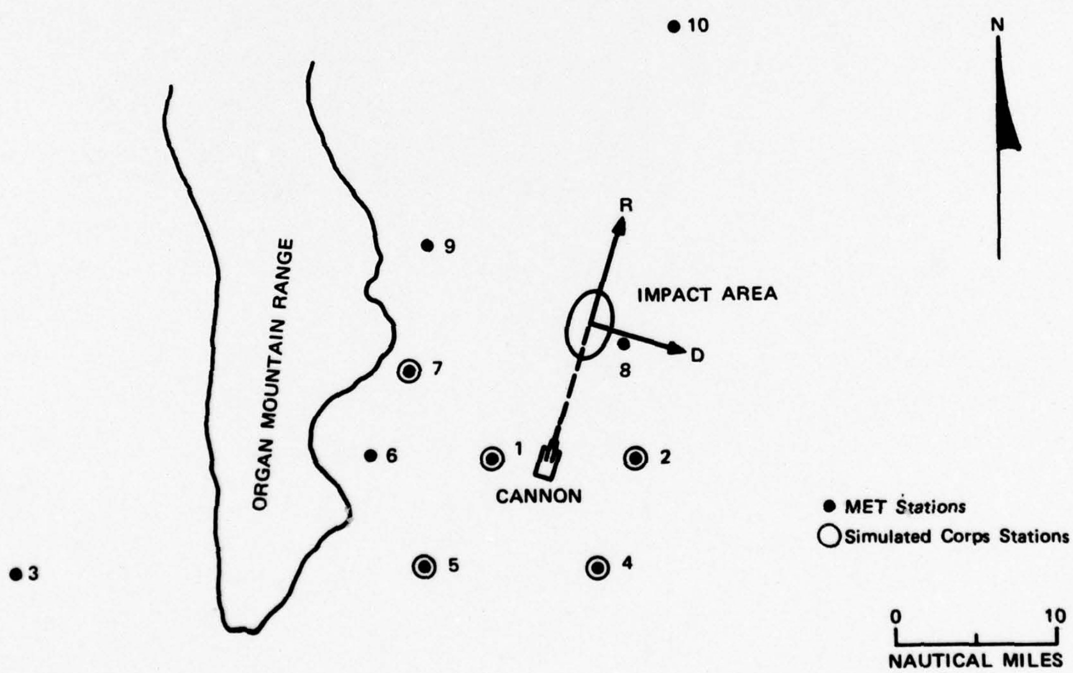

FIGURE 1 UPPER-AIR SOUNDING STATIONS AND ARTILLERY FIRING-IMPACT EMPLACEMENTS — PASS FIELD EXPERIMENTS

The PASS data were used recently by Blanco and Traylor (1976) to compare different methods of providing artillery MET messages. They found that methods based on multistation analyses did not provide significantly better input for the artillery firings than did the standard method of using upper-air observations of a single dedicated station. However, the larger firing errors were during days when the wind changed significantly over time periods of one to three hours. This indicates that accurate forecasts of the changing meteorological conditions should lead to significantly improved artillery accuracy. The ARTY/GWC method, tested in this study, is an attempt to provide such forecast MET messages by utilizing the U.S. Air Force GWC prognostic products.

II THE ARTY/GWC METHOD

The ARTY/GWC method was developed and implemented in the form of computer programs in a previous study (Mancuso and Hadfield, 1976). Flow diagrams of the various computer programs used in the present study are shown in Figures 2 and 3. The GWC prognostic products and

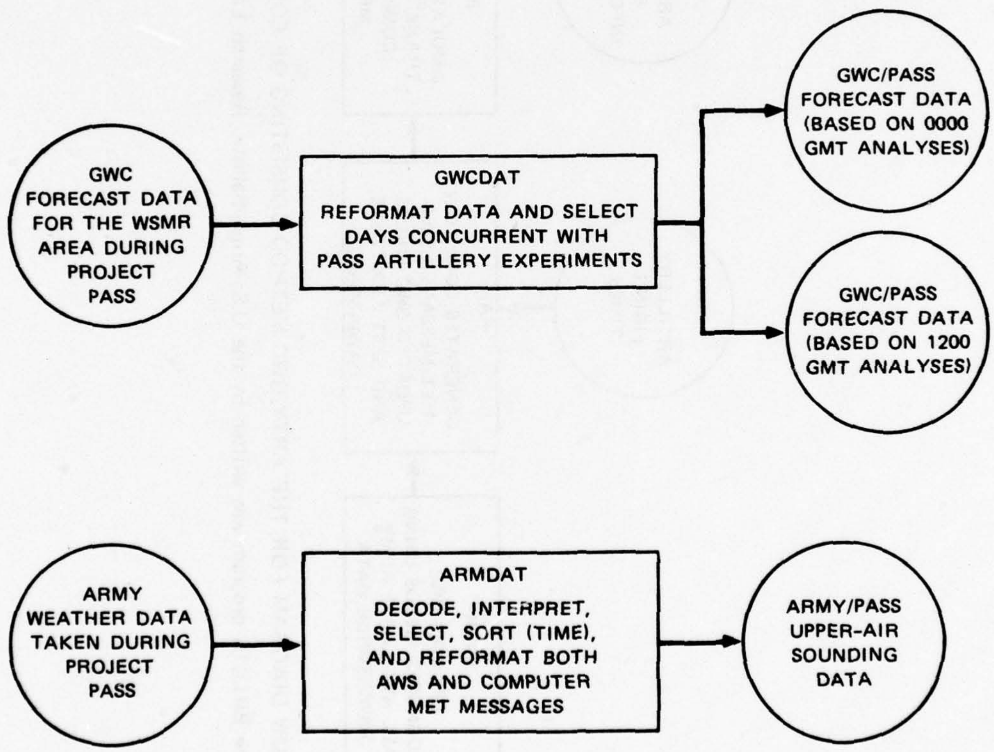

FIGURE 2 FLOW DIAGRAMS FOR THE DATA PROCESSING PROGRAMS — GWCDAT and ARMDAT

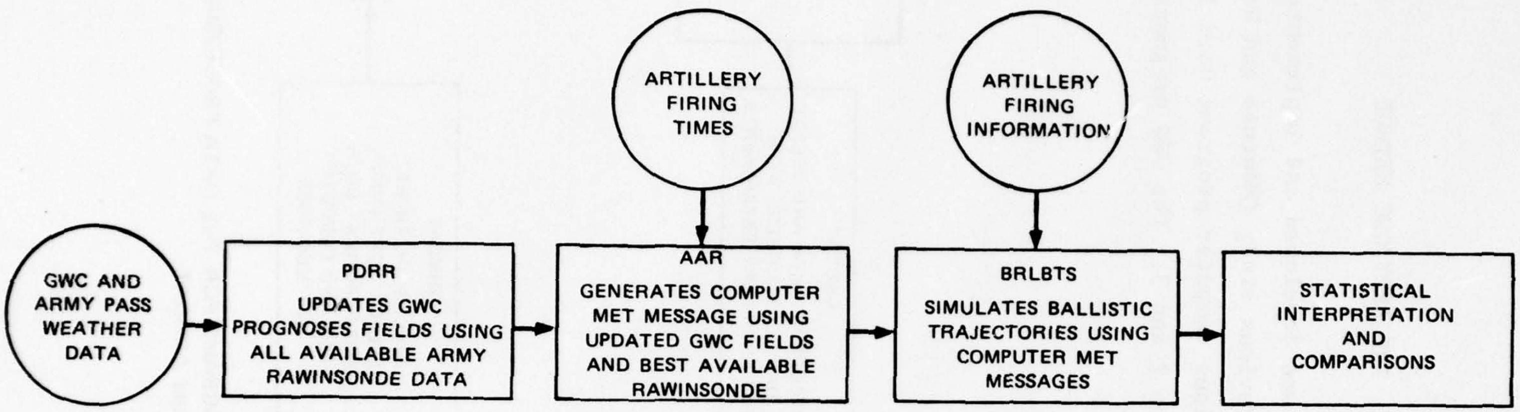

FIGURE 3 FLOW DIAGRAM FOR THE ARTY/GWC METHOD CONSISTING OF COMPUTER PROGRAMS PDRR AND AAR
(The BRLBTS program was written by the U.S. Army Ballistic Research Laboratory.)

U.S. Army upper-air data for the project PASS period were first processed using the computer programs GWCDAT and ARMDAT (Figure 2). These programs converted the data into a form suitable for the ARTY/GWC programs. The ARMDAT routine also decodes, identifies, selects, and orders (chronologically) the various types of meteorological sounding data that were collected during project PASS.

The computer programs of the ARTY/GWC analysis method consist of the Prognostic Data Reanalysis Routine (PDRR) and the Artillery Applications Routine (AAR) as illustrated in Figure 3. The PDRR uses U.S. Army weather data to update the GWC prognostic fields at the mandatory levels. The GWC analysis and prognostic data are used initially to determine the speed and direction of the weather pattern movements by using a pattern-tracking technique developed by Wolf (Mancuso and Wolf, 1974). The GWC data are then interpolated onto a minigrid that provides the basic structure for performing the remaining computations. The Army upper-air sounding data are used to update the GWC prognostic fields. The Army observations are grouped within 40-minute time intervals, and are treated as sets of data occurring at the midpoint of the time intervals. The first set of observations is used to initially update the GWC prognostic fields. This updating consists of obtaining new grid-point values based on both the Army upper-air observations and GWC grid-point values. The new grid-point values are computed by a least-squares fitting of a first-degree polynomial to nearby data, using an elliptical distance weighting (Mancuso and Wolf, 1974). Difference fields between the original and updated GWC prognostic fields are then computed. These difference fields are moved with the speed and direction of the GWC patterns, and are used to update the GWC prognostic fields at later times. Second and subsequent sets of Army observations are similarly used to further update the most recently updated GWC fields.

The output of the PDRR program (updated GWC fields) is used as input by the AAR program. In the AAR computer program, an updated GWC sounding profile is constructed for the specified time and location of the cannon firing. A guide profile is also used to aid in interpolating between mandatory levels. The guide profile is obtained either from:

- A single dedicated station
- The best available station, or by
- A multistation analysis.

The latter of these is based on a first-degree polynomial fit of distance-weighted data as in the updating analysis. However, in the case where only the simulated Corps stations are used (Figure 1), then the multistation analysis is reduced to a simpler distance-weighted averaging of the data. The latter is similar to the distance- and time-weighted algorithm of Blanco and Traylor (1976). The AAR program is also used to convert the final updated GWC profile into a computer MET message format (U.S. Army, 1970). The output of the AAR program (computer MET message) is used as input by the Ballistics Research Laboratory's Ballistic Trajectory Simulation (BRLBTS) program.

Various improvements and corrections to the previously developed PDRR and AAR programs (Mancuso and Hadfield, 1976) have been made in this study, in particular to give an optimum analysis and editing of the data. Listings for the program routines that have been modified are given in Appendices A and B. The unlisted routines in addition to the procedures for reading in program control parameters are identical to those given previously.

III PASS AND GWC DATA

The PASS upper-air measurements and cannon firings were made at the times shown in Figure 4. The PASS data for December 5th and 7th could not be used, since the GWC prognostic data were available only through 1800 GMT of December 5th. Also, the initial firings on November 12th and 14th were excluded so that the simulations could be based entirely on the GWC prognostic products that were derived from 1200 GMT analyses. Thus, a total of 61 firing cases were used in this study.

The PASS upper-air measurements were made at the ten different stations shown in Figure 1, with five of these sites being used to simulate an operational Corps MET network. T9 radar wind measurements were made every hour, while AN/GMD-1B rawinsonde measurements were made every two hours; one-half hour separated the MET observations made at Corps sites from those made at non-Corps sites. One type of data input that was used in this study, and referred to as GMD, was based mainly on the rawinsonde data. However, each rawinsonde observation was updated at the following hour by replacing the rawinsonde winds with the more recent T9 radar winds. A second type of data input that was used, and referred to as GMD/T9, consisted of winds based entirely on the T9 radar wind measurements. However, this latter type of input was inferior, because the T9 winds were less complete and not as reliable as the standard rawinsonde winds.

The PASS upper-air measurements had been converted in the field into both computer MET messages and Air Weather Service (AWS) MET messages. Computer MET messages were prepared using both the GMD and GMD/T9 type data. However, the AWS MET messages were prepared using only the GMD/T9 type data.

FIGURE 4 TIMES OF UPPER-AIR MEASUREMENTS (A and B) AND ARTILLERY FIRINGS (*) DURING PROJECT PASS, 1974
(T9 radar wind measurements were made every hour, while rawinsonde measurements were made every two hours)

	11 12 13 14 15 16 17 18 19 20 21 22 23 24 GMT
6 NOV	A B A B A B A B A B (No Artillery Firings)
7 NOV	A B A B A B A B A B A B A B A B A B (No Artillery Firings)
8 NOV	A B A*B A*B A $\overset{*}{B}$ A*B
11 NOV	A B A*B A*B A*B A B
12 NOV	A B A*B A*B A*B A B
14 NOV	A B A*B A*B A*B A*B A*B A*B A*B A*B
15 NOV	A B A B A*B A*B A*B A*B A*B A $\overset{*}{B}$ A*B
18 NOV	A B A B A*B A*B A*B
19 NOV	A B A*B A B A*B A*B
20 NOV	A B A*B A*B A*B A*B
23 NOV	A B A*B A*B A*B A*B A*B A*B A*B A*B
26 NOV	A B A*B A*B A*B A*B
27 NOV	A B A*B A*B A*B A*B
2 DEC	A B A*B A*B A*B A*B A*B A*B A*B A*B
3 DEC	A B A*B A*B A*B A*B
5 DEC	A B A*B A*B A*B A*B A*B A*B (No GWC Data)
7 DEC	A B A*B A*B A*B A*B A*B A*B A*B A*B A*B A*B (No GWC Data)

A: UPPER-AIR OBSERVATIONS AT MET STATIONS 1, 2, 4, 5, 7

B: UPPER-AIR OBSERVATIONS AT MET STATIONS 3, 8, 9, 10

IV SIMULATION APPROACH

The approach used in this study to evaluate the ARTY/GWC method was based on the Ballistics Trajectory Simulation program developed by the U.S. Army Ballistics Research Laboratory. With this program the point of impact is computed in terms of the range (R) and a cross component or deflection (D). The difference between a simulated point of impact (R_s, D_s) and an actual point of impact (R_a, D_a) is caused by errors associated with the:

- Interpolation or extrapolation of meteorological data in both time and space
- Meteorological measurements
- Location of the actual impact (R_a, D_a)
- Quadrant elevation and azimuth angles
- Muzzle velocity
- Projectile characteristics (weight, shape, etc.).

Measured values for these last four elements are actually based on mean or representative values for a series of cannon shots that were made within a relatively short time interval about a given firing time.

In order to evaluate the ARTY/GWC method, cannon firing simulations were made for the 61 cases using MET messages from the ARTY/GWC method and from more basic methods. The error variability of any given set of simulations was described by the mean and standard deviation of the quantities:

$$\Delta R = R_a - R_s ,$$
$$\Delta D = D_a - D_s . \tag{1}$$

The standard deviations of these quantities ($\sigma_{\Delta R}$ and $\sigma_{\Delta D}$) and a probable error (PE) are used primarily for comparing methods, assuming that the mean deviations either are due to other sources of errors or would approach zero if the sample size was increased. It is important, however,

to consider the mean departures if they differ significantly. Error ellipses were constructed for comparison purposes using standard statistical theories for elliptical frequency distributions (Brooks and Carruthers, 1953). The probable error (PE) as defined in this report is the radius of a circle about the mean which contains 50% of the impact points.

V SIMULATION RESULTS

A. GMD Data

The initial simulations of cannon firings were made using a multistation analysis of all available GMD type data within ±20 minutes of the firing times. This is equivalent to having instant data, and is not realistic for Army operations with present measurement systems. However, such simulations demonstrate the accuracy that would be possible with accurate meteorological forecasting. The multistation analysis was based on a first-degree polynomial fit of surrounding data weighted inversely with distance, and is the same as the third guide profile referred to in Section II. The results for these initial simulations are shown in Figure 5a, next to those that were obtained by using a standard atmosphere with zero winds (Figure 5b). These figures show the differences between the actual and simulated impact locations ($\Delta R, \Delta D$), computed according to eqs (1). Since the location of the simulated impact may be thought of as being the intended or desired target, the figures are similar to a typical shooting target. As discussed previously, errors from several sources cause the differences or target misses that are displayed in Figures 5a and b. The simulation results that were based on the multistation analysis (Figure 5a) have a probable error (PE) of 39m, while the results for the standard atmosphere (Figure 5b) have a PE value of 108m. The latter also has a significant mean error that is not reflected in the PE value. These two results illustrate the importance of meteorology in artillery ballistics.

Four different types of simulation results are shown in Figure 6, again using data ±20 minutes of the firing times. Figure 6a repeats the firing simulation results for the multistation analysis that were shown in Figure 6a (using an expanded scale), while Figure 6b shows simulation results that were based on a simple average of meteorological profiles of the five closest stations. This latter type of analysis gave a firing error distribution (Figure 6b) very similar to that obtained

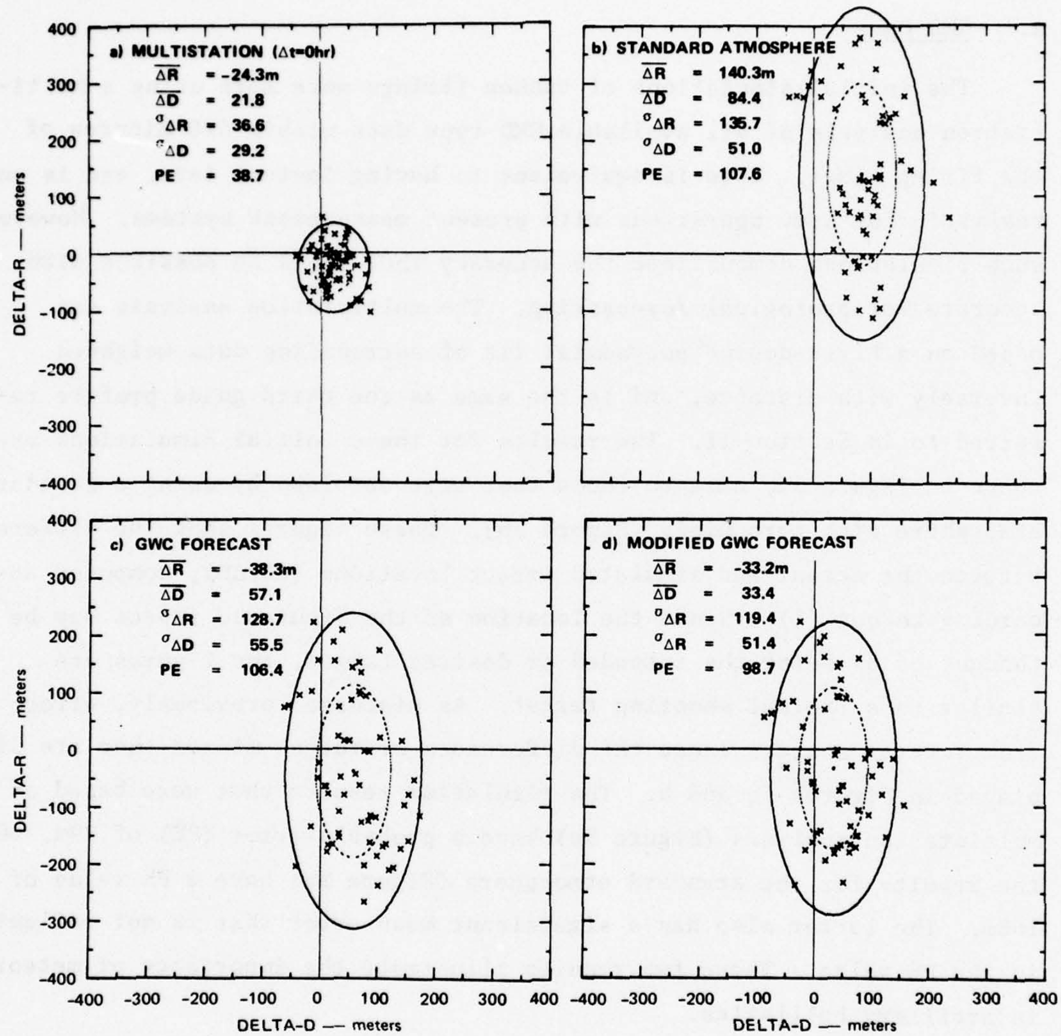

FIGURE 5 DIFFERENCES BETWEEN ACTUAL AND SIMULATED IMPACT LOCATIONS, USING A MULTISTATION ANALYSIS OF THE GMD TYPE DATA (a), STANDARD ATMOSPHERE (ZERO WINDS) (b), GWC DATA (c), AND MODIFIED GWC DATA (d).

(The dashed line shows the 50% error ellipse, the solid line shows the 90% error ellipse, and the dot shows the mean deviation or ellipse center.)

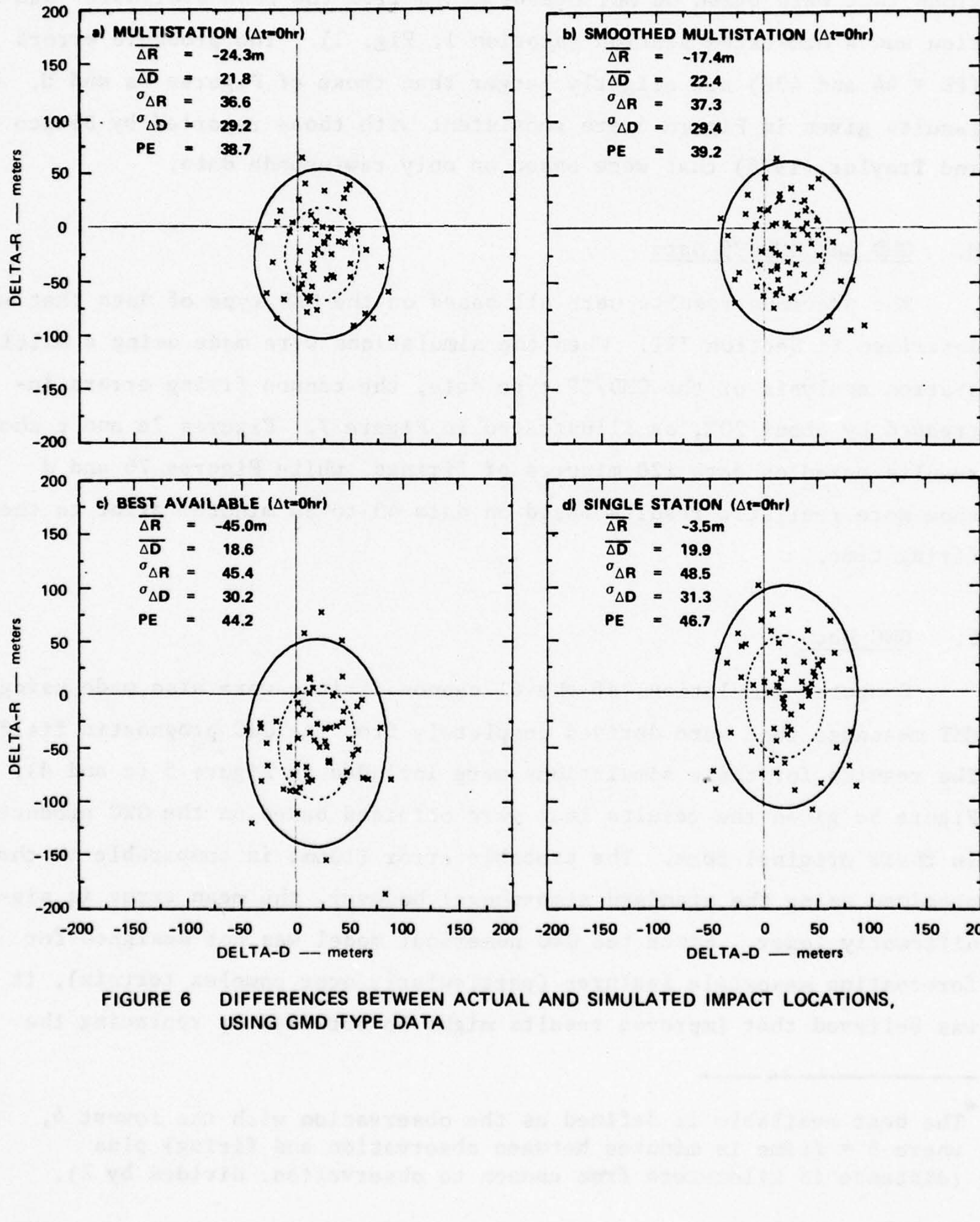

FIGURE 6 DIFFERENCES BETWEEN ACTUAL AND SIMULATED IMPACT LOCATIONS, USING GMD TYPE DATA

with the more delineating type of analysis (Figure 6a). This suggests that the space interpolation errors have become relatively unimportant, and that the scatter shown in both Figures 6a and b is principally due either to rawinsonde measurement errors or to non-meteorological errors.

The results shown in Figures 6c and d are for cannon firing simulations that were based on MET measurements from the best available* station and a dedicated station (station 1, Fig. 1). The probable errors (PE = 44 and 47m) are slightly larger than those of Figures 6a and b. The results given in Figure 6 are consistent with those reported by Blanco and Traylor (1976) that were based on only rawinsonde data.

B. GMD and GMD/T9 Data

The previous results were all based on the GMD type of data that were described in Section III. When the simulations were made using a multistation analysis of the GMD/T9 type data, the cannon firing errors increased by about 20%, as illustrated in Figure 7. Figures 7a and c show results based on data ±20 minutes of firings, while Figures 7b and d show more realistic results based on data 40 to 80 minutes prior to the firing time.

C. GWC Data

Computer simulations of the 61 cannon firings were also made using MET messages that were derived completely from the GWC prognostic fields. The results for these simulations were included in Figure 5 (c and d). Figure 5c gives the results that were obtained based on the GWC products in their original form. The probable error (106m) is comparable to that obtained using the standard atmosphere; however, the mean error is significantly lower. Since the GWC numerical model was not designed for forecasting mesoscale features (particularly over complex terrain), it was believed that improved results might be obtained by replacing the

*The best available is defined as the observation with the lowest δ, where δ = (time in minutes between observation and firing) plus (distance in kilometers from cannon to observation, divided by 2).

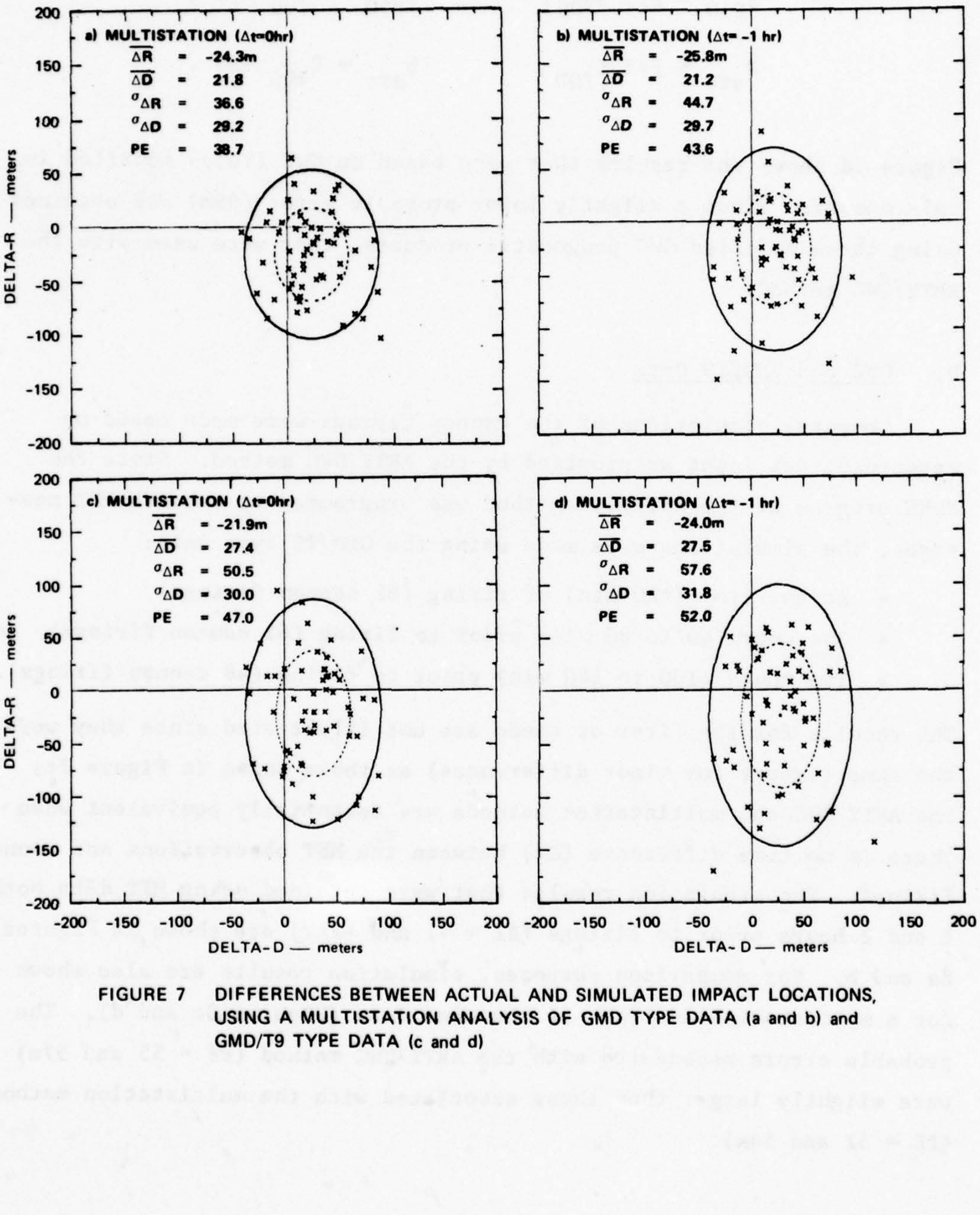

FIGURE 7 DIFFERENCES BETWEEN ACTUAL AND SIMULATED IMPACT LOCATIONS, USING A MULTISTATION ANALYSIS OF GMD TYPE DATA (a and b) and GMD/T9 TYPE DATA (c and d)

wind fields at the surface (~880 mb) and at 850 mb with ones that were estimated from the 700 mb wind field. To account in an approximate fashion for surface friction effect on wind speed (S) and direction (θ), these estimations were made as follows:

$$S_{850} = 2/3\ S_{700}, \qquad \theta_{850} = \theta_{700} - 10°,$$

$$S_{sfc} = 1/3\ S_{700}, \qquad \theta_{sfc} = \theta_{700} - 20°.$$

Figure 5d shows the results that were based on GWC fields modified in this manner. Since a slightly lower probable error (99m) was obtained using these modified GWC prognostic products, they were used with the ARTY/GWC method.

D. GWC and GMD/T9 Data

Computer simulations of the cannon firings were made based on meteorological input as provided by the ARTY/GWC method. Since the PDRR program of the ARTY/GWC method was programmed to use AWS MET messages, the simulations were made using the GMD/T9 type data:

- At the time (±20 min) of firing (61 cannon firings)
- One hour (40 to 80 min) prior to firing (61 cannon firings), and
- Two hours (100 to 140 min) prior to firing (48 cannon firings).

The results for the first of these are not illustrated since they were the same (except for minor differences) as those shown in Figure 7c; the ARTY/GWC and multistation methods are essentially equivalent when there is no time difference (Δt) between the MET observations and cannon firings. The simulation results that were obtained using MET data both 1 and 2 hours prior to firings (Δt = -1 and -2hr) are shown in Figures 8a and b. For comparison purposes, simulation results are also shown for a multistation analysis of the same data (Figures 8c and d). The probable errors associated with the ARTY/GWC method (PE = 55 and 57m) were slightly larger than those associated with the multistation method (PE = 52 and 54m).

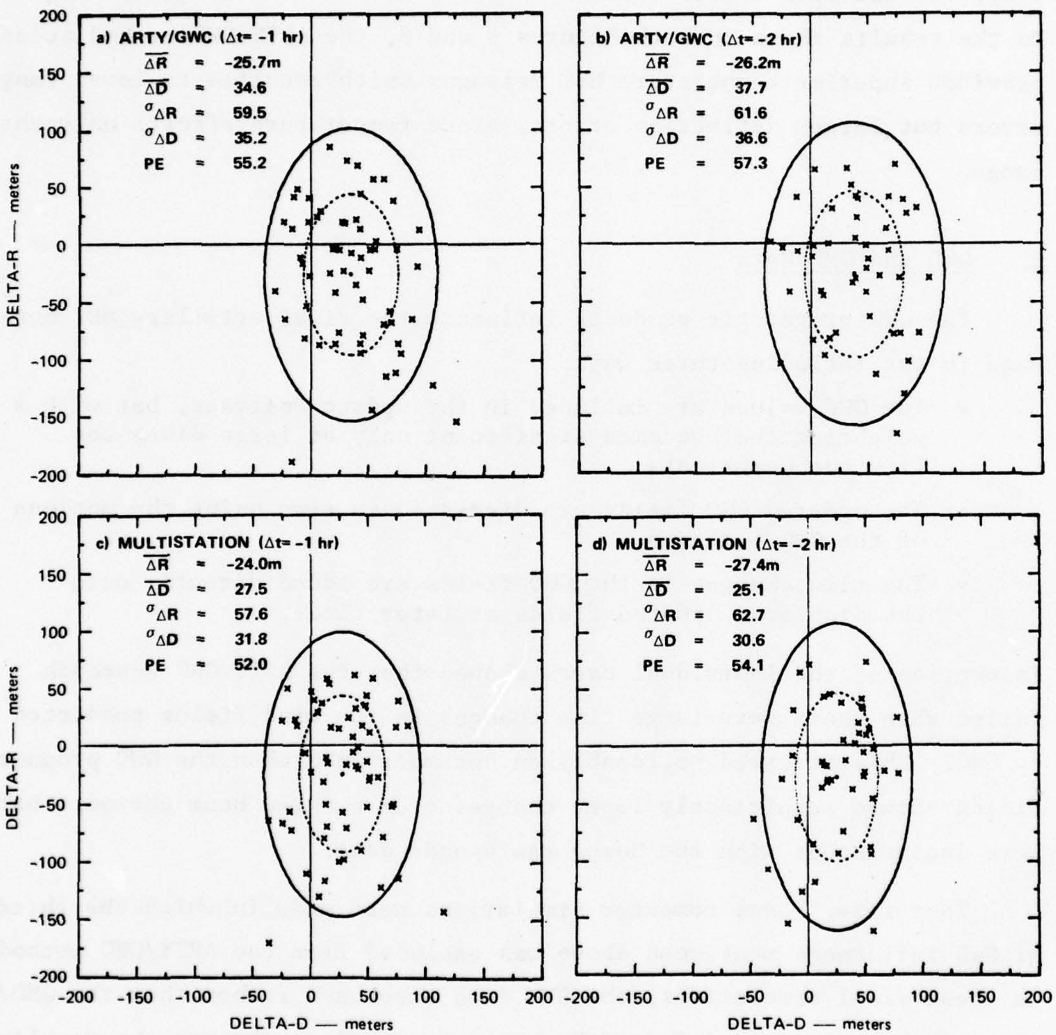

FIGURE 8 DIFFERENCES BETWEEN ACTUAL AND SIMULATED IMPACT LOCATIONS, USING GMD/T9 TYPE DATA

In the above experiments, all of the MET stations in Figure 1 were utilized. When the more realistic set of simulated Corps stations designated in Figure 1 was used, then the results shown in Figure 9 were obtained. In these simulation experiments, the ARTY/GWC gave comparable results to those of the multistation method (54 and 56m versus 53 and 57m), but the mean errors for the ARTY/GWC method were slightly larger. In the results shown in both Figures 9 and 8, the ARTY/GWC method actually provided superior temperature MET messages which resulted in lower range errors but larger deflection errors, since temperature affects only the range.

E. GWC and GMD Data

The GWC prognostic products influence the final artillery MET message in the following three ways:

- The GWC values are included in the update analyses, but with a weighting that becomes significant only at large distances from the Corps data.
- The updated GWC fields are displaced in time using the motions of the GWC patterns.
- The time changes in the GWC fields are added directly onto the displaced updated fields at later times.

Inspection of the individual cases showed that the ARTY/GWC approach failed when there were large time changes in the wind fields predicted by GWC. This occurred noticeably on December 2nd, when the GWC prognostic fields showed suspiciously large changes over a three hour period, that were inconsistent with the Corps rawinsonde data.

Therefore, final computer simulations were made in which the third of GWC influences mentioned above was excluded from the ARTY/GWC method. In these final simulations, the GMD data were used rather than the GMD/T9, since the errors associated with the latter tend to obscure the results. This required a special program for converting computer MET messages into AWS MET messages. The firing errors that were associated with using data both 1 and 2 hours prior to the firings (Δt = -1hr and -2hr) are shown in Figures 10a to d. The ARTY/GWC forecast method gave only slightly

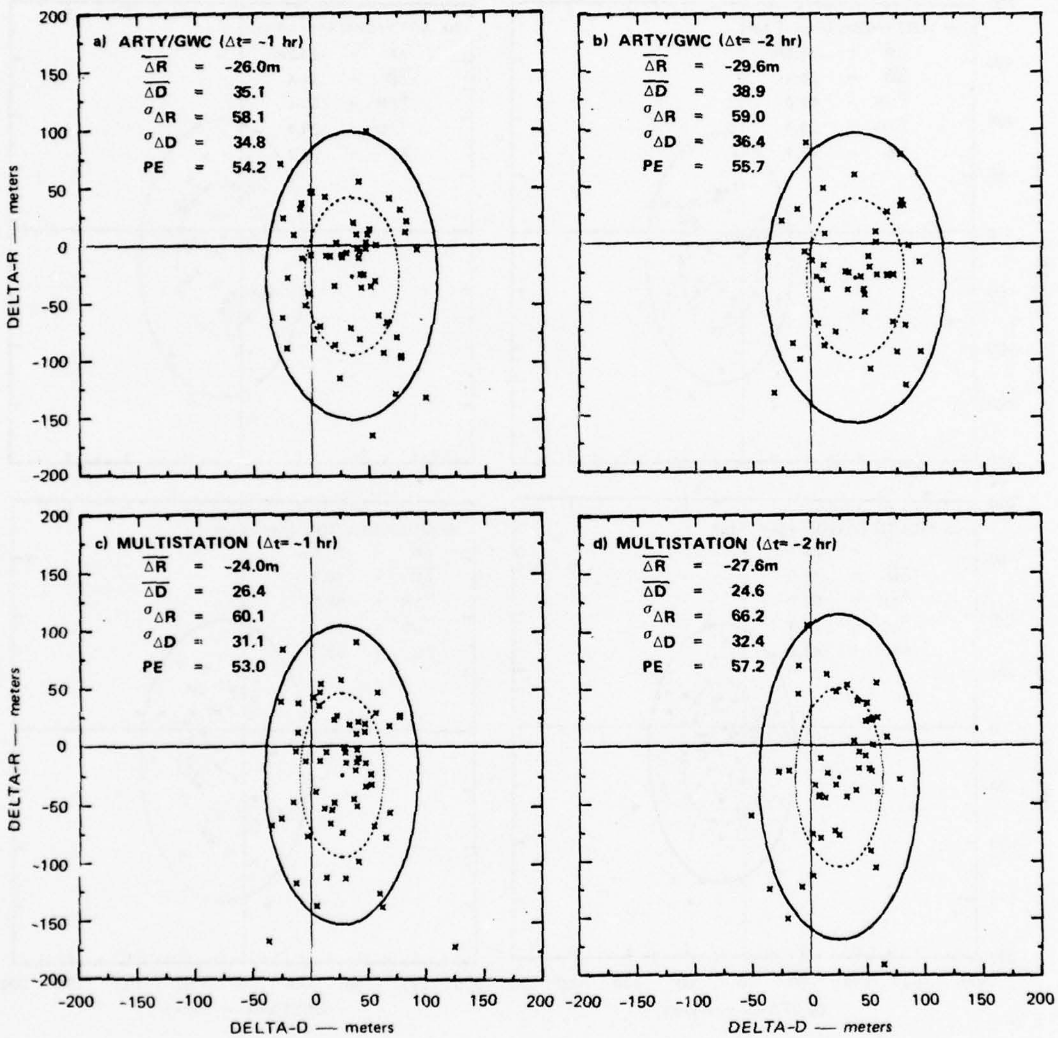

FIGURE 9 DIFFERENCES BETWEEN ACTUAL AND SIMULATED IMPACT LOCATIONS, USING GMD/T9 DATA, RESTRICTED TO CORPS STATIONS (See Figure 1)

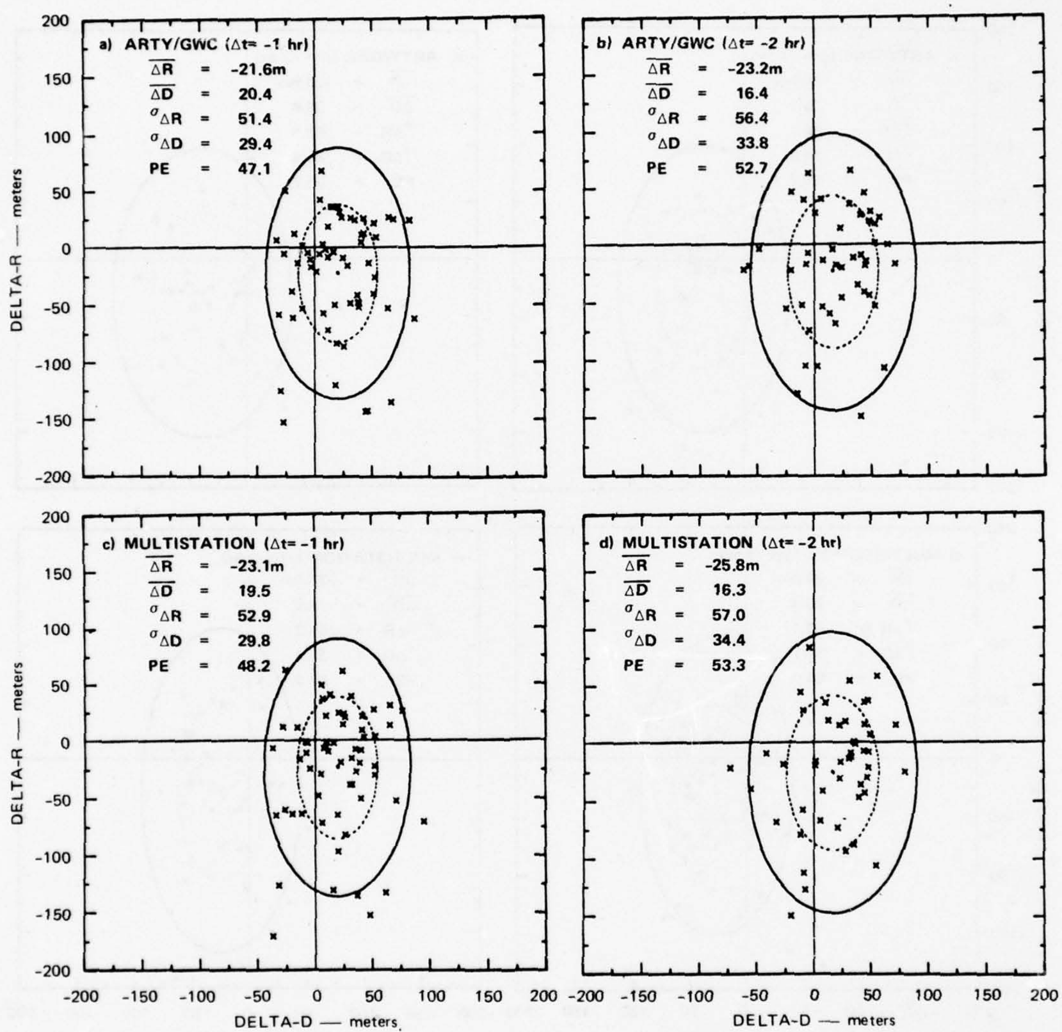

FIGURE 10 DIFFERENCES BETWEEN ACTUAL AND SIMULATED IMPACT LOCATIONS, USING GMD TYPE DATA, RESTRICTED TO CORPS STATIONS (See Figure 1)

smaller probable errors than did the multistation persistence method (47 and 52m versus 48 and 53m).

The ΔR and ΔD values for individual cases are listed in Appendix C for the results shown in Figures 5, 6, and 10.

VI CONCLUSIONS AND RECOMMENDATIONS

This study showed that a significant reduction (25% to 50%) in artillery firing errors is possible, if wind and temperature profiles for the time and location of the artillery firing can be accurately determined, either by direct measurements or by accurate forecasting. The ARTY/GWC method for providing forecast artillery MET messages, that was tested, provided results statistically equivalent to simpler persistence methods. This indicates that the GWC prognostic products are not yet sufficiently accurate and detailed for use in artillery ballistics. If more advanced GWC models become available, which are designed to treat limited and relocatable window regions on a mesoscale basis, then the ARTY/GWC or similar method could prove to be highly effective.

In this study, no attempt was made to include the influence of complex terrain in the ARTY/GWC updating analyses. In actual military operations, this would frequently be of greater importance than it is in the White Sands areas. Theoretical and diagnostic techniques such as those that have been developed by Estoque and Bhumralkar (see Estoque et al., 1976), can be used to investigate the influence that terrain has upon the meteorological fields, with regard both to roughness and surface heating. Research along this line is currently being carried out at SRI International.

Appendix A

LISTING OF MODIFIED PDRR PROGRAM

Appendix A

LISTING OF MODIFIED PDRR PROGRAM

```
      PROGRAM   PDRR(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3,TAPE4,TAPE5=INPUT,
     2               TAPE9,PUNCH)

C THIS PROGRAM IS THE PROGNOSTIC DATA REANALYSIS ROUTINE (PDRR). IT IS
C  USED FOR REANALYZING OR UPDATING THE GLOBAL WEATHER CENTER (GWC)
C  PROGNOSTIC DATA USING THE MOST RECENTLY AVAILABLE ARMY UPPER AIR
C  OBSERVATIONS.
C AUG 1977 VERSION: - CONTAINS IMPROVEMENTS SUCH AS TEMPERATURE EDITING,
C  OPTIMIZED PARAMETER VALUES, AND MORE ACCURATE COMPUTATION OF GWC
C  PATTERN MOTIONS.
C
C DIMENSION AND COMMON STATMENTS
C
      INTEGER DATA(12000)
      DIMENSION U(100),V(100),H(100),T(100),VOR(100),DIV(100),BAL(100)
      DIMENSION US(25),VS(25),HS(25),TS(25),XS(25),YS(25),ES(25)
      DIMENSION X(10),Y(10),DSX(100),DSY(100),LDATE(5,25),IMD(12)
      DIMENSION CM(10),TM(10),TRU(100),TRV(100),XRU(100),XRV(100)
      DIMENSION DAT1(400),GAT1(100),GAT2(100),VAT(25),WAT(25),GAS(100,4)
      DIMENSION UR(100),VR(100),HR(100),TR(100)
      COMMON/CIS/ IS(1000)
      COMMON/CCHK/ CRT,SIM,GIM,IWND
      COMMON/CGD/ M9,N9,I9,M8,N8,YB,XB,DD
      COMMON/CPTS/    KS,W1,C2,RMAX,KSS5,IDS,KSW,ALPH
      EQUIVALENCE (U,GAS(1,1)),(V,GAS(1,2)),(H,GAS(1,3)),(T,GAS(1,4)),
     2            (UR,DAT1(1)),(VR,DAT1(101)),(HR,DAT1(201)),
     3            (TR,DAT1(301)),(VOR,DSX),(DIV,DSY)
C
C SET BASIC CONSTANTS (INITIALLY SET CORE TO ZERO)
C
      DATA XNIL,TMAX,TMIN/-999.9,310.0,230.0/
      DATA IBCK, IDIF,IGMT /0,20,-420/
      DATA I0,I1,I2/0,1,2/
      DATA  NVARP,NSIZE /3,5/
      DATA CRT,SIM,GIMS,IWND/ 0.3,0.10,0.05,1/
      DATA W1,C2,RMAX,KS,KSS5,KSW,IDS,ALPH/0.01,0.005,10.0,10,5,4,1,2.0/
      DATA I20,L1,L4,L100,K4,N5,N25 /16,1,4,100,4,5,25/
      DATA XP,YP,ROT,DTS,ACR/24.0,26.0,80.0,1.0,0.0174533/
      DATA  IMD/0,31,59,90,120,151,181,212,243,273,304,334/
    1 FORMAT(10X,7I10)
    2 FORMAT(10X,2I10,5F10.2)
    3 FORMAT(10X,I10)
    4 FORMAT(14X,3I2,6X,2I2)
    5 FORMAT(10X,I10)
    6 FORMAT(10X,3F10.2)
    7 FORMAT(2X,6I10,2E15.3)
    8 FORMAT(2X,4E15.3)
    9 FORMAT(2X,6HDELETE,I10,4F7.2)
   10 FORMAT(10X,5F10.2)
C
C READ IN CONTROL PARAMETERS
C
      READ (5,1) ICHK,IANA,IDIV,IBAL,IFOR,IPRINT,ITAPE
      READ (5,2)N9,M9,XB,YB,DD,XC,YC
      READ (5,5) JT
      READ (5,6) (XS(J),YS(J),ES(J),J=1,JT)
```

```
C
C PRINT OUT CONTROL PARAMETERS
C
      PRINT 9000
      PRINT 9100
      PRINT 9000
      PRINT 9050
      PRINT 9001,ICHK,IANA,IDIV,IBAL,IFOR,IPRINT,ITAPE
      PRINT 9002,N9,M9,XB,YB,DD,XC,YC
      PRINT 9005,JT
      PRINT 9056
      PRINT 9006,(J,XS(J),YS(J),ES(J),J=1,JT)
C
C PERFORM BASIC COMPUTATIONS
C
      IF (JT.GT.25) GO TO 999
      IF (M9.GT.10.OR.N9.GT.10) GO TO 999
      ACRI=1.0/ACR
      GIM=GIMS
      X100=DTS*60.0
      I9=M9*N9
      M8=M9-1
      N8=N9-1
      N49=I9
      N98=N49+N49
      N47=N98+N49
      K3=K4-1
      IO=L4*K3*N49
      DO 20 N=1,N9
   20 X(N)=XB+DD*(N-1)
      XAVE=ACR*(-X(N5)-ROT)
      SAVE=SIN(XAVE)
      CAVE=COS(XAVE)
      DO 22 M=1,M9
      Y(M)=YB-DD*(M-1)
      ANG=ACR*Y(M)
      CM(M)=COS(ANG)
   22 TM(M)=TAN(ANG)
      XN5=-X(N5)
      CGD=1.0+Y(N5)/90.0
      CALL MESH(IO,JT,YS,XS,VS,US,HS,TS,Y,X,V,U,H,T)
C
      IH20=(I20-1)*60
      DO 23 I=1,100
      TRU(I)=0.0
   23 TRV(I)=0.0
      I=0
      DO 24 M=1,M9
      TLA=TAN((90.0-Y(M))*ACR*0.5)*31.2042
      DO 24 N=1,N9
      I=I+1
      XLO=ACR*(-X(N)-ROT)
      DSX(I)=(XP-TLA*SIN(XLO)-XC)*2.0+1.0
   24 DSY(I)=(YP+TLA*COS(XLO)-YC)*2.0+1.0
      READ (5,3) IT
```

```
      READ (5,4) ((LDATE(L,I),L=1,5),I=1,IT)
      PRINT 9003,IT
      PRINT 9054
      PRINT 9004,((LDATE(L,I),L=1,5),I=1,IT)
C
C
C LOOP THROUGH ALL GWC FORECASTING TIMES
C
      DO 50 IG=1,I20
C
C READ IN GWC DATA
C
      CALL GWCIN(IG,IGWC,JDATE,JTIME,DAT1,IMD)
   31 DO 45 L=L1,L4
      N1=(L-1)*L100
      IP=((IG-1)*L4+L-1)*I9*K3
      JP=0
      DO 42 K=1,K4
      IF (K.EQ.K4) IP=IP-N49
      DO 36 N=1,N25
      N1=N1+1
      DATN=DAT1(N1)
      WAT(N)=DATN
      IF (K.GT.2) GO TO 35
      N3=N1
      IF (K.EQ.2) N3=N1-N25
      DATN=DAT1(N3)
      VATN=DAT1(N3+N25)
      WAT(N)=DATN
      IF (K.EQ.2) WAT(N)=VATN
      IF (K.EQ.2) DATN=VATN
   35 JP=JP+1
      GAT1(JP)=GAS(JP,L)
      GAS(JP,L)=DATN
      GAT2(JP)=DATN
   36 VAT(N)=DATN
      DO 40 I=1,I9
      DLX=DSX(I)
      DLY=DSY(I)
      NX=INT(DLX)
      MY=INT(DLY)
      NM=(MY-1)*N5+NX
      DLX=DLX-NX
      DLY=DLY-MY
C
C INTERPOLATE TO MINI GRID
C
      CALL INTPT(NM,N5,VAT,DLX,DLY,BAT)
      IP=IP+1
      IBAT=INT(BAT*10.0)
      IF (K.EQ.3) IBAT=IBAT*10000
      IF(K.NE.4) GO TO 40
      IF(DATA(IP).LT.0) IBAT=-IBAT
      IBAT=DATA(IP)+IBAT
   40 DATA(IP)=IBAT
```

```
   42 CONTINUE
C
C COMPUTE TRENDS
C
      IF (IFOR.LT.1.OR.IG.LT.2) GO TO 45
      LIG=(IG-1)*L4+L
      NVARS=NVARP
      CALL TREND(NVARS,NSIZE,TRU(LIG),TRV(LIG),GAT1,GAT2,IG)
      TRU(LIG)=TRU(LIG)*CGD
      TRV(LIG)=-TRV(LIG)*CGD
      CALL UVCONV(TRU(LIG),TRV(LIG),XN5)
      TRU(LIG)=TRU(LIG)/DD
      TRV(LIG)=TRV(LIG)/DD
      TRUV=TRU(LIG)*TRU(LIG)+TRV(LIG)*TRV(LIG)
      IF (TRUV.LT.16.0) GO TO 44
      TRFC=4.0/SQRT(TRUV)
      TRU(LIG)=TRU(LIG)*TRFC
      TRV(LIG)=TRV(LIG)*TRFC
   44 CONTINUE
   45 CONTINUE
   50 CONTINUE
      ILT=I20*L4
      DO 55 L=L1,L4
      DO 55 IG=2,I20
      LIG=(IG-1)*L4+L
      SUM=2.0
      USUM=TRU(LIG)*2.0
      VSUM=TRV(LIG)*2.0
      DO 54 IGX=1,3
      XIGX=1.0/IGX
      LID=LIG+IGX*L4
      IF (LID.GT.ILT) GO TO 53
      SUM=SUM+XIGX
      USUM=USUM+TRU(LID)*XIGX
      VSUM=VSUM+TRV(LID)*XIGX
   53 LID=LIG-IGX*L4
      IF (LID.LT.1) GO TO 54
      SUM=SUM+XIGX
      USUM=USUM+TRU(LID)*XIGX
      VSUM=VSUM+TRV(LID)*XIGX
   54 CONTINUE
      SUM=1.0/SUM
      XRU(LIG)=USUM*SUM
      XRV(LIG)=VSUM*SUM
   55 CONTINUE
      PRINT 9025
      DO 56 L=L1,L4
      DO 56 IG=2,I20
      LIG=(IG-1)*L4+L
      TRU(LIG)=XRU(LIG)
      TRV(LIG)=XRV(LIG)
      PRINT 2,IG,L,TRU(LIG),TRV(LIG)
   56 CONTINUE
C
C END OF GWC LOOP
```

```
C
      PRINT 2,JP,IP
C
C LOOP THROUGH ARMY RAWINSONDE OBSERVATION TIMES
C
      DO 100 IR=1,IT
      IF (IANA.LT.1) GO TO 101
      I=IR
      LD2=LDATE(2,I)
      IDATE=LDATE(5,I)+60*(LDATE(4,I)+24*(LDATE(3,I)+IMD(LD2)
     2      +365*LDATE(1,I)-366))-IBCK
      PRINT 1,IGWC,IDATE
      IF (IDATE.LT.IGWC) GO TO 999
      IF (IDATE.GT.IGWC+IH20) GO TO 999
      ICOMP=IGWC+X100
      DO 60 IG=2,I20
      IF (IDATE-ICOMP) 58,60,60
   58 FG1=(ICOMP-IDATE)*0.1/X100
      FG2=0.1-FG1
      GO TO 61
   60 ICOMP=ICOMP+X100
      GO TO 999
   61 IG=IG-1
      IG1=IG+1
      IL=(IG-1)*ID
      PRINT 1,ICOMP,IDATE,IG
      PRINT 6,FG1,FG2
C
C READ IN RAWINSONDE DATA
C
      I=IR+IGD-1
      CALL RAWIN(JT,I, ES,UR,VR,HR,TR,IMD,IDATE,IDIF,IGMT)
C
C LOOP THROUGH MANDATORY LEVELS
C
      DO  95 L=L1,L4
      LJ=(L-1)*JT
      DO 68 J=1,JT
      US(J)=UR(J+LJ)
      VS(J)=VR(J+LJ)
      HS(J)=HR(J+LJ)
   68 TS(J)=TR(J+LJ)

      N1=IL+(L-1)*N49*K3+1
      N2=N1+N49-1
      I=1
      DO 70 N=N1,N2
      U(I)=DATA(N)*FG1+DATA(N+ID)*FG2
      V(I)=DATA(N+N49)*FG1+DATA(N+N49+ID)*FG2
      IH1=INT(DATA(N+N98    )*0.0001)
      IH2=INT(DATA(N+N98+ID)*0.0001)
      IT1=DATA(N+N98    )-IH1*10000
      IT2=DATA(N+N98+ID)-IH2*10000
      IT1=IABS(IT1)
      IT2=IABS(IT2)
```

```
      H(I)= IH1*FG1+IH2*FG2
      T(I)= IT1*FG1+IT2*FG2
   70 I=I+1
      PRINT 9000
      PRINT 9059,L
      SUMT=0.0
      NUMT=0
      DO 166 J=1,JT
      IF (TS(J).LT.TMIN .OR.TS(J).GT.TMAX ) GO TO 166
      SUMT=SUMT+TS(J)
      NUMT=NUMT+1
  166 CONTINUE
      IF (NUMT.LT.1) GO TO 169
      SUMT=SUMT/NUMT
      DO 168 J=1,JT
      ABTS=ABS(TS(J)-SUMT)
      IF (ABTS.LT.8.0) GO TO 168
      IF (TS(J).LT.0.0) GO TO 167
      PRINT 9,J,TS(J),HS(J),US(J),VS(J)
  167 TS(J)=XNIL
      HS(J)=XNIL
      US(J)=XNIL
      VS(J)=XNIL
  168 CONTINUE
  169 CONTINUE
      IF (ICHK.LE.0.OR.L.EQ.1)  GO TO 170
                        CALL CHECK(JT,YS,XS,VS,US,Y,X,V,U)
  170 CONTINUE
      PRINT 9057
      PRINT 9007,(J,HS(J),TS(J),US(J),VS(J),J=1,JT)
      IF (IPRINT.LT.1) GO TO 71
      PRINT 9060
      PRINT 9062
      PRINT 9010,(H(I),I=1,I9)
      PRINT 9064
      PRINT 9010,(T(I),I=1,I9)
      PRINT 9066
      PRINT 9010,(U(I),I=1,I9)
      PRINT 9068
      PRINT 9010,(V(I),I=1,I9)
   71 CONTINUE
      IF (IANA) 95,95,73
   73 DO 173 I=1,I9
      VOR(I)=0.0
      DIV(I)=0.0
  173 BAL(I)=0.0
      IF (IDIV.GT.0)
     1CALL KID(IO,I1,IO,VOR,DIV,BAL,U,V,CM,TM)
      CALL MESH(I2,JT,YS,XS,VS,US,HS,TS,Y,X,V,U,H,T)
      IF (IDIV.LT.0) GO TO 75
C
C ADJUSTMENT OF WIND FIELD TO THE GWC DIVERGENCE FIELD
C
      CALL KID(I1,IO,IO,VOR,BAL,DIV,U,V,CM,TM)
      CALL ALTERS(25.0,0.0.5,TM, CM, U,V,VOR,DIV)
```

```
   75 IF (IBAL.LT.1) GO TO 85
C
C COMPUTATION OF BALANCED HEIGHT FIELD
C
      CALL KID(I0,I0,I1,VOR,DIV,BAL,U,V,CM,TM)
      SUM=0.0
      DO 80 I=1,I9
   80 SUM=SUM+H(I)
      AVE=SUM/I9
      CALL  BALHGT(M9,N9,DD,1,10,1,2,.01,AVE,CM,TM,H,BAL)
   85 CONTINUE
      IF (IPRINT.LT.1) GO TO 86
      PRINT 9000
      PRINT 9070
      PRINT 9062
      PRINT 9010,(H(I),I=1,I9)
      PRINT 9064
      PRINT 9010,(T(I),I=1,I9)
      PRINT 9066
      PRINT 9010,(U(I),I=1,I9)
      PRINT 9068
      PRINT 9010,(V(I),I=1,I9)
   86 CONTINUE
      IF (IFOR.LT.1) GO TO  95
C
C UPDATE ALL GWC FORECAST FIELDS BY ADVECTING WITH COMPUTED TRENDS
C
      DO 90 IH=IG,I20
      N1=(IH-1)*ID+(L-1)*K3*N49+1
      N2=N1+N49-1
      DT=DTS
      LIH=(IH-1)*L4+L
      IF (IH.GT.IG1) GO TO 88
      LIH=LIH+L4
      DT=-FG2*10.0*DTS
      IF (IH.EQ.IG) GO TO 187
      DT= FG1*10.0*DTS
      DO 186 I=1,I9
      U(I)=XRU(I)
      V(I)=XRV(I)
      H(I)=VOR(I)
  186 T(I)=DIV(I)
      GO TO 88
  187 I=1
      DO 87 N=N1,N2
      U(I)=DATA(N)*FG1+DATA(N+ID)*FG2-U(I)
      V(I)=DATA(N+N49)*FG1+DATA(N+N49+ID)*FG2-V(I)
      IH1=INT(DATA(N+N98   )*0.0001)
      IH2=INT(DATA(N+N98+ID)*0.0001)
      IT1=DATA(N+N98    )-IH1*10000
      IT2=DATA(N+N98+ID)-IH2*10000
      IT1=IABS(IT1)
      IT2=IABS(IT2)
      H(I)= IH1*FG1+IH2*FG2-H(I)
      T(I)= IT1*FG1+IT2*FG2-T(I)
```

```
      XRU(I)=U(I)
      XRV(I)=V(I)
      VOR(I)=H(I)
      DIV(I)=T(I)
   87 I=I+1
   88 CONTINUE
      CALL ADVEC(DT,TRU(LIH),TRV(LIH),U,BAL,CM)
      CALL ADVEC(DT,TRU(LIH),TRV(LIH),V,BAL,CM)
      CALL ADVEC(DT,TRU(LIH),TRV(LIH),H,BAL,CM)
      CALL ADVEC(DT,TRU(LIH),TRV(LIH),T,BAL,CM)
      I=1
      DO 89 N=N1,N2
      DATA(   N)=DATA(   N)-U(I)*10
      DATA(N+N49)=DATA(N+N49)-V(I)*10
      IH1=INT(DATA(N+N98    )*0.0001)
      IT1=DATA(N+N98    )-IH1*10000
      IT1=IABS(IT1)
      IH2=IH1-H(I)*10.0
      IT2=IT1-T(I)*10.0
      IF(IH2.LT.0) IT2=-IT2
      DATA(N+N98)=IH2*10000+IT2
   89 I=I+1
   90 CONTINUE
   95 CONTINUE
C
C END OF LEVEL LOOP
C
C
C WRITE OUT UPDATAD FIELDS ON TAPE3
C
  101 CONTINUE
      IF (ITAPE.LT.1) GO TO 99
      PRINT 1,   JDATE,JTIME,I20
      WRITE (3) JDATE,JTIME,I20
      DO 98 IH=1,I20
      DO 98 L=L1,L4
      N1=(IH-1)*ID+(L-1)*K3*N49+1
      N2=N1+N49-1
   98 WRITE (3) (DATA(N),DATA(N+N49),DATA(N+N98),N=N1,N2)
   99 CONTINUE
  100 CONTINUE
C
C END OF ARMY LOOP
C
      END FILE 3
  197 READ (1) IDUM
      IF (EOF(1)) 200,197
  200 CONTINUE
      GO TO 1000
  999 PRINT 9999
 1000 CONTINUE
 9000 FORMAT(1H1)
 9001 FORMAT(2X,8HCARD A   ,7I10//)
 9002 FORMAT(2X,8HCARD B   ,2I10,5F10.2//)
 9003 FORMAT(2X,8HCARD C   ,I10//)
```

```
9004 FORMAT(8X,5I10/)
9005 FORMAT(/2X,8HCARD E   ,I10,//)
9006 FORMAT(10X,I5,5X,3F10.2/)
9007 FORMAT(16X,I2,2X,4F10.2)
9010 FORMAT(1P,10X,7F6.0)
9025 FORMAT(1H )
9050 FORMAT(30X,27HINPUT DATA FOR PDRR ROUTINE///)
9054 FORMAT(2X,57HCARDS D         YEAR      MONTH       DAY        HOUR
    2 MIN/)
9056 FORMAT(2X,8HCARDS F ,9X,20HSTATION  INFORMATION//12X,10HNUMBER
    2      ,30HLONGITUTE  LATITUTE  ELEVATION/)
9057 FORMAT(25X,13HSTATION  DATA// 9X,33H      NUMBER  D VALUE  TEMPERAT
    2URE,    19H  U COMP     V COMP ,/)
9059 FORMAT(10X,22HRESULTS FOR LEVEL L = ,I1//)
9060 FORMAT(20X,21HGWC DATA ON MINI GRID//)
9062 FORMAT(/24X,8HD VALUES/)
9064 FORMAT(/23X,11HTEMPERATURE/)
9066 FORMAT(/26X,6HU COMP/)
9068 FORMAT(/26X,6HV COMP/)
9070 FORMAT(15X,29HUPDATED GWC DATA ON MINI GRID//)
9100 FORMAT(///45X,34HPROGNOSTIC DATA REANALYSIS ROUTINE,//////
    2///,    57X,5HUNITS,///,53X,11HSPEED - MPS,//,53X,15HDIRECTION - DE
    3G,//,   53X,15HHEIGHT - METERS,//,53X,19HTEMPERATURE - DEG K)
9999 FORMAT(10X,23HINCONSISTENT INPUT DATA)
     STOP
     END
```

```
      SUBROUTINE  RAWIN(JT,I,ES,UR,VR,HR,TR,IMD,IDATE,IDIF,IGMT)
C
C THIS SUBROUTINE READS IN THE U S ARMY RAWINSONDE DATA.
C AUG 1977 VERSION: - MODIFIED TO SELECT DATA TYPES IT=4 OR 5 ONLY, AND
C  TO INTERPOLATE AND EXTRAPOLATE WHEN WIND PROFILES ARE INCOMPLETE.
C
      DIMENSION  UR(1),VR(1),HR(1),TR(1),ES(1),IMD(1)
      DIMENSION  DAT(512),IS(25),HOZ(17),PRS(6),STD(6),COR(6)
      DIMENSION  IR(50)
      DATA ACR,CKM,CC,XNIL/0.0174533,0.5148,29.29,-999.9/
      DATA J10,J17,J24,J28,J51,K4/10,12,24,28,51,4/
      DATA  STD/   0.0,1457.0,3012.0,5574.0,0.0,0.0/
      DATA  PRS/ 870.0,850.0,700.0,500.0,300.0,200.0/
      DATA  HOZ/0.0,100.0,350.0,750.0,1250.0,1750.0,2250.0,2750.0,3250.0
     2      ,3750.0,4250.0,4750.0,5500.0,6500.0,7500.0,8500.0,9500.0/
      DATA  COR/-3.8,-3.1,-0.1,0.5,0.0,0.0/
      SPDMX=100.0
      ESST=1300.0
      DO 18 L=1,JT
   18 IS(L)=11
      JK= JT*K4
      DO 19 L=1,JK
      IR(L)=0
      HR(L)=XNIL
      TR(L)=XNIL
      UR(L)=XNIL
   19 VR(L)=XNIL
      IFIL=0
      IF (I.GT.1) GO TO 22
C
C READS IN DATA SET
C
   20 READ (9)  DAT
      IF (EOF(9))124,21
  124 IFIL=IFIL+1
      IF (IFIL.GT.1) GO TO 32
      GO TO 20
C
C LOOP THROUGH DATA SET IN RECORD
C
   21 CONTINUE
      DO 30 J=1,J10
   22 JC=(J-1)*J51+1
C
C CHECKS DATA FOR DATE,TIME,AND TYPE
C
      IF (DAT(JC).LT.0.0) GO TO 30
      IP1=INT(DAT(JC)*1.0E-4)
      DATJ=DAT(JC)-IP1*1.0E4
      IP2=INT(DATJ*1.0E-2)
      IP3 =DATJ-IP2*1.0E2
      IP4=INT(DAT(JC+1)*0.01)
      IP5=DAT(JC+1)-IP4*100
      JDATE=IP5+60*(IP4+24*(IP3+IMD(IP2)+365*IP1-366))-IGMT
    5 FORMAT(2X,5I12)
```

```
      IF (JDATE.LT.IDATE-IDIF) GO TO 30
      IF (JDATE.GT.IDATE+IDIF) GO TO 32
      JS=INT(DAT(JC+2)*0.1)
      IT  =DAT(JC+2)-JS*10
      IF (IT.LT.4.OR.IT.GT.6) GO TO 30
      NDATE=INT(DAT(JC))
      NTIME=INT(DAT(JC+1))
      ESJS=ES(JS)
C
C SELECTS OUT HEIGHTS AND TEMPERATURES FOR THE MANDATORY LEVELS
C
      K=1
      DO 26 JQ=4,J24,4
      JK=(K-1)*JT +JS
      JCQ=JC+JQ
      IF (K.EQ.1) GO TO 25
      IF (K.GT.K4) GO TO 27
      IF (DAT(JCQ).NE.PRS(K)) GO TO 26
   25 IF (DAT(JCQ-1).LT.0.0) GO TO 125
      IF     (IT.GT.IS(JS).AND.TR(JK).GT.0.0) GO TO 125
      HR(JK)=DAT(JCQ-1)-STD(K)
      TR(JK)=DAT(JCQ+1)+273.16
      IF (K.NE.1) GO TO 125
      PRS1=((ESJS-ESST)/(TR(JK)*CC)+1.0)*DAT(JCQ)
                    HR(JK)=-(DAT(JCQ)- PRS1 )*TR(JK)*CC/DAT(JCQ)
  125 K=K+1
   26 CONTINUE
   27 KT=K-1
C
C INTERPOLATES ZONAL WIND VALUES TO OBTAIN VALUES FOR MANDATORY LEVELS
C
      JCJ=JC+J28-1
      IF (ABS(DAT(JCJ+1)).GT.SPDMX) GO TO 127
      ANG=ACR*DAT(JCJ)
      IF     (IT.GT.IS(JS).AND.ABS(UR(JS)).LT.SPDMX) GO TO 127
      UR(JS)=-DAT(JCJ+1)*SIN(ANG)*CKM
      VR(JS)=-DAT(JCJ+1)*COS(ANG)*CKM
  127 J2=2
      DO 29 K=2,KT
      JK=(K-1)*JT +JS
      HRJK=HR(JK)+STD(K)
      DO 28 JH=J2,J17
      JG=JCJ+(JH-1)*2
      JI=JG+1
      IF (ABS(DAT( JI)).LE.SPDMX) GO TO 128
      IF (ABS(DAT(JI-2)).GT.SPDMX) GO TO  28
      DAT(JG)=DAT(JG-2)
      DAT(JI)=DAT(JI-2)
      GO TO 129
  128 IR(JK)=1
      IF (ABS(DAT(JI-2)).LE.SPDMX)GO TO 129
      DAT(JG-2)=DAT(JG)
      DAT(JI-2)=DAT(JI)
  129 IF (HOZ(JH)+ESJS.LT.HRJK)    GO TO 28
      IF     (IT.GT.IS(JS).AND.IR(JK).EQ.1) GO TO 29
```

```
      RH=  (HRJK-HOZ(JH-1)-ESJS)/(HOZ(JH)-HOZ(JH-1))
      UR(JK)=(-RH*DAT(JI)*SIN(ACR*DAT(JG))+DAT(JI-2)*SIN(ACR*DAT(JG-2))*
     2(RH-1.0))*CKM
      VR(JK)=(-RH*DAT(JI)*COS(ACR*DAT(JG))+DAT(JI-2)*COS(ACR*DAT(JG-2))*
     2(RH-1.0))*CKM
      GO TO 29
   28 CONTINUE
      GO TO 130
   29 J2=JH
  130 CONTINUE
      IF (IT.LT.IS(JS)) IS(JS)=IT
   30 CONTINUE
      GO TO 20
   32 CONTINUE
      JSM=0
      DO 150 L=1,JT
      IF (IS(L).LT.11)JSM=JSM+1
  150 CONTINUE
      PRINT 1,JSM
    1 FORMAT(10X,37HU S ARMY RAWINSONDE DATA READ IN FOR ,I2,9H-STATIONS
    2      ,//)
      RETURN
      END
```

```
      SUBROUTINE CHECK  (JJ,YS,XS,VS,US,YL,XL,VN,UN)
C
C THE SUBROUTINE CHECKS THE OBSERVED WIND VALUES BY COMPARING THEM
C  TO ANALYZED WIND VALUES  (THE U AND V OF THE INCONSISTENT DATA ARE
C  SET AT 999.9 ).
C AUG 1977 VERSION: - MODIFIED SO THAT ANALYZED WINDS ARE BASED ON A
C  WEIGHTED AVERAGING OF DATA, WHICH IS MORE SUITABLE FOR USE WITH THE
C  PORR PROGRAM.
C
C  JJ = NUMBER OF WIND DATA
C  YS,XS = LATITUDE AND LONGITUDE OF WIND DATA (DEG)
C  US,VS = U AND V COMPONENTS OF WIND DATA
C  YL,XL = LATITUDE AND LONGITUDE OF ROWS AND COLUMNS
C  UN,VN = GRID POINT U AND V WIND COMPONENTS
C  CRT= CRITICAL VALUE USED IN TESTING WIND DATA
C  WIM= WEIGHT GIVEN TO A WIND IN ANALYZING A VALUE AT ITS LOCATION
C       AND WEIGHT GIVEN TO NEAREST GRID POINT VALUE (NOW CALLED SIM AND
C       GIM)
C
      LOGICAL DEBUG
      DIMENSION JST( 26),DST( 26),WTS( 25),DVR(20)
      DIMENSION XS( 1),YS( 1),VS( 1),US( 1)
      DIMENSION XL( 1),YL( 1),UN( 1),VN( 1)
      COMMON/CIS/ IS(1000)
      COMMON/CCHK/ CRT,SIM,GIM,IWND
      COMMON/CPTS/    KS,W1,C2,RMAX,KSS5,IDS,KSW,ALPH
      COMMON/CGD/ M9,N9,I9,M8,N8,YB,XB,DD
      EQUIVALENCE (USK,USJ),(VSK,VSJ)
      EQUIVALENCE (DVR(1),DNH),(DVR(2),DHH),(DVR(3),DUH),(DVR(4),DVH),
     2  (DVR(5),DTH),(DVR(6),DXH),(DVR(7),DYH),(DVR(8),DXYH),
     3  (DVR(9),DXXH),(DVR(10),DYYH),(DVR(11),DXHH),(DVR(12),DXUH),
     4  (DVR(13),DXVH),(DVR(14),DYHH),(DVR(15),DYUH),(DVR(16),DYVH),
     5  (DVR(17),DXTH),(DVR(18),DYTH)
      DATA  DEBUG/.FALSE./
      DEBUG=.TRUE.
    4 FORMAT(21X,,13H DELETED DATA/)
    5 FORMAT (49H      LAT(DEG)  LON(DEG)  U(KTS)    V(KTS)    TEST,/)
    6 FORMAT(1X,10F10.2)
      PRINT 4
      PRINT 5
C
C BASIC COMPUTATIONS
C
      JT=JJ
      ACR=3.1416/180.0
      YDI=1.0/DD
      XDI=1.0/DD
      KQ5=KSS5+2
      IF (IWND.GT.0) KQ5=KQ5+1
      SPH1=ALPH*ALPH
      CR5=1.25*CRT
C
C ANALYSIS OF WINDS  AT MEASUREMENT LOCATIONS (SIMILAR TO METHOD USED
C  IN SUBROUTINE MESH).
C
```

```
      KG=0
   20 JX=0
      LX=0
      CRW=CR5
      IF (KG.EQ.2) CRW=CRT
   80 LX=LX+1
      IF (LX-JT)  82,82,100
   82 L=LX
      IF (KG.NE.0) L= JST(LX)
      IF (ABS(US(L)).GT.100.0) GO TO 80
      YLM=YS(L)
      XLN=XS(L)
      M=(YL(1)-YLM)*YDI+1.5
      N=(XLN-XL(1))*XDI+1.5
      IF (M.LT.1) M=1
      IF (M.GT.M9)  M=M9
      IF (N.LT.1) N=1
      IF (N.GT.N9)  N=N9
      LI=N9*(M-1)+N
      I=(LI-1)*KS
      CM=COS(ACR*YLM)
      NOD=0
      K=0
      DO 182 IK=1,18
  182 DVR(IK)=0.0
      IF (IWND.LE.0) GO TO 84
      XSJ=XL(N)
      YSJ=YL(M)
      USJ=UN(LI)
      VSJ=VN(LI)
      DYS=YSJ-YLM
      DXS=(XSJ-XLN)*CM
      W=GIM
      GO TO 89
   84 K=K+1
      IF (K-KS) 85,85,90
   85 I=I+1
      IF (NOD-KQ5)   86,84,84
   86 J=IS(I)
      IF (J)    84,84,87
   87 IF (ABS(US(J)).GT.100.0) GO TO 84
      USJ=US(J)
      VSJ=VS(J)
      XSJ=XS(J)
      YSJ=YS(J)
      DYS=YSJ-YLM
      DXS=(XSJ-XLN)*CM
      W=SIM
      IF (J.EQ.L) GO TO 389
      DXS2=0.0
      DYS2=DYS*DYS+DXS*DXS
      IF (IDS.LT.1) GO TO  88
      DXS1=USK*USK+VSK*VSK+0.01
      DXS2=(USK*DYS-VSK*DXS)
      DXS2=DXS2*DXS2/DXS1
```

```
   88 W=C2/(DYS2+DXS2*SPH1+C2)
  389 IF (KG.NE.0)  W=W*WTS(J)
   89 NOD=NOD+1
      DNH=DNH+W
      DUH=DUH+USJ*W
      DVH=DVH+VSJ*W
      GO TO 84
   90 IF (NOD.LT.3) GO TO 80
      IF (DNH.LE.0.0) GO TO 80
      DNH=1.0/DNH
      ULL=DUH*DNH
      VLL=DVH*DNH
C
C CHECK FOR FOR INCONSISTENCY BETWEEN ANALYZED AND MEASURED WINDS
C
      ALTH1= ULL*ULL+VLL*VLL
      ALTH2= US(L)*US(L)+VS(L)*VS(L)
      BLTH=ALTH1
      IF(ALTH2 .GT. ALTH1) BLTH= ALTH2
      PERP1=(ULL*US(L) +VLL*VS(L))/BLTH
      IF (DEBUG)
     2PRINT 6, YS(L),XS(L),US(L),VS(L),PERP1,ULL,VLL,CRW,CR5,CRT
      DLS=PERP1
      WTS(L)=1.0
      IF (DLS.GT.CR5) GO TO 80
      WTS(L)=0.5
      IF (DLS.GT.CRW)  GO TO 80
      IF (KG.EQ.2)  GO TO 99
      WTS(L)=SIM
      IF (JX.GT.25)   GO TO 100
      JX=JX+1
      JST(JX) =L
      DST(JX) = PERP1
      GO TO 80
   99 PRINT 6, YS(L),XS(L),US(L),VS(L),PERP1
      US(L) =-999.9
      VS(L) =-999.9
      GO TO 80
  100 CONTINUE
C
C ORDER SUSPECT DATA ACCORDING TO HIGHEST PERP1 VALUES AND REPEAT ABOVE
C
      IF (JX.LE.0) GO TO 300
      JT=JX
      IF (KG.EQ.0) GO TO 202
      IF (KG.NE.1) GO TO 300
      DO 200 J1=1,JT
      J3=J1
      DO 150 J2=J1,JT
      IF (DST(J2) .LT. DST(J3))  J3=J2
  150 CONTINUE
      IST=JST(J1)
      XST=DST(J1)
      JST(J1)=JST(J3)
      DST(J1)=DST(J3)
```

```
      JST(J3)=IST
      DST(J3)=XST
  200 CONTINUE
  202 KG=KG+1
      GO TO 20
  300 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ADVEC(DT,US,VS,Q1,Q2,CM)
C
C THIS SUBROUTINE ADVECTS THE FIELD Q1 WITH A SPECIFIED WIND.
C AUG 1977 VERSION: - MODIFIED TO GIVE A STABLE ADVECTION COMPUTATION
C  UNDER ALL INPUT CONDITIONS.
C
C  DT = TIME STEP OVER WHICH ADVECTION IS MADE
C  US,VS = COMPONENTS OF WIND USED TO ADVECT Q1 FIELD
C  Q1 = FIELD THAT IS ADVECTED
C  Q2 = DUMMY FIELD
C  CM = COSINES OF ROW LATITUDES
C
      DIMENSION Q1(1),Q2(1),CM(1)
      COMMON/CGD/ M9,N9,I9,M8,N8,Y8,X8,DD
      XID=1.0
      YID=XID*N9
      TT=DT
      UT=US
      VT=VS
      IT=1
      DO 20 IR=1,10
      IF (ABS(UT).LE.1.0.AND.ABS(VT).LE.1.0)  GO TO 22
      UT=0.5*UT
      VT=0.5*VT
      TT=0.5*TT
   20 IT=IT+IT
   22 CON =ABS(TT)
      DO 200 IR=1,IT
      I=1
      DO 100 M=1,M9
      CMI=1.0/CM(M)
      DO 100 N=1,N9
      Q1I=Q1(I)
      UA=ABS(UT)*CMI
      VA=ABS(VT)
      IF (DT.LT.0.0) GO TO 80
      IU=N-SIGN(XID,UT)
      IV=I+SIGN(YID,VT)
      GO TO 90
   80 IU=N+SIGN(XID,UT)
      IV=I-SIGN(YID,VT)
   90 Q1V=0.0
      Q1U=0.0
      IF (IV.GT.0.AND.IV.LE.I9) Q1V=Q1(IV)
      JU=IU+(M-1)*N9
      IF (IU.GT.0.AND.IU.LE.N9) Q1U=Q1(JU)
      Q2(I)=Q1I-((Q1I-Q1U   )*UA+(Q1I-Q1V   )*VA)*CON
  100 I=I+1
      DO 150 I=1,I9
  150 Q1(I)=Q2(I)
  200 CONTINUE
      RETURN
      END
```

Appendix B

LISTING OF MODIFIED AAR PROGRAM

Appendix B

LISTING OF MODIFIED AAR PROGRAM

```
      PROGRAM AAR(INPUT,OUTPUT,TAPE1,TAPE3,TAPE5=INPUT,
     1                  TAPE6=OUTPUT,TAPE7)
C
C     PROGRAM AAR READS VARIOUS INPUT DATA DESCRIBED AS COMMENTS IN
C     IN PROGRAM AND COMPUTES A FINAL FORECAST CURVE (HEIGHT,VIRTUAL
C     TEMP IN DEG.C. ,U AND V COMP.) FOR A SPECIFIED FIRING TIME AND
C     FIRING LOCATICN
C AUG 1977 VERSION: - CONTAINS IMPROVEMENTS SUCH AS THE ADDITION OF SUB-
C  ROUTINE BEST THAT PROVIDES AN ANALYZEC GUIDE PROFILE, AND OPTIMIZED
C  PARAMETER VALUES.
C
      DOUBLE PRECISION XX,YY,XL,YL,RAD
      INTEGER ABCDEF(14),GHIJKL(10),MNOPQR(10)
      INTEGER H1(7,7),T1(7,7),U1(7,7),V1(7,7)
      DIMENSION HH(49,4,2),TV(49,4,2),U(49,4,2),V(49,4,2),XMILS1(21),
     1HHFNAL(4,2),TVFNAL(4,2),UFINAL(4,2),VFINAL(4,2),XNOTS1(21)
      DIMENSION JSAV(5),TIM(5),CDIS(21),XNDU(21),XNDV(21),XNDTC(21),
     1XNDT(21),XNDH(21),XNOTS2(21),XMILS2(21),DIFSEC(21)
      DIMENSION UF(21),VF(21),TF(21),HF(21),PF(21),PFD(5),X(7),Y(7)
      DIMENSION   UR(12,12),VR(12,12),HR(12,12),TR(12,12)
      DIMENSION UZ(144),VZ(144),TZ(144),HZ(144),PZ(144)
      DIMENSION IUM(147),XS(25),YS(25),ES(25),IMD(12),PR(12,12)
      DIMENSION HHTFG(5),STV(5),       HHTF(5),TVTF(5),UTF(5),VTF(5)
      DIMENSION US(12),VS(12),HS(12),TS(12),PS(12)
      DIMENSION STTF(12),STPF(12),STHF(12)
      COMMON /FMT/ XLAB
      COMMON/CPTS/   KS,W1,C2,RMAX,KSS5,IDS,KSW,ALPH
      EQUIVALENCE(I7,NX),(J7,NY)
      EQUIVALENCE (UR,UZ),(VR,VZ),(TR,TZ),(HR,HZ),(PR,PZ)
      DATA STV/111.0,1457.0,3012.0,5574.0,0.0/
      DATA IBCK, IDIF,IGMT/0,20,-420/
      DATA L1,L4,L12/1,4,12/
      DATA IND,YMAX,YMIN/21,300.0,1000.0/
      DATA JSAV/10,1,9,10,10/
      DATA TIM /170C.,1830.,2000.,2130.,2300./
      DATA PFD/883.0,850.0,700.0,500.0,300.0/
      DATA IMD/0,31,59,90,120,151,181,212,243,273,304,334/
      DATA W1,C2,KS,KSS5,IDS,ALPH/0.04,0.005,10,10,1,2.0/
      DATA NIL,XNIL/-999,-999.9/
      DATA STHF/0.0,100.0,350.0,750.0,1250.0,1750.0,2250.0,2750.0,3250.0
     2       ,3750.0,4250.0,4750.0/
      DATA STPF/874.0,863.0,837.0,797.0,749.0,703.0,659.0,618.0,579.0,
     2           542.0,506.0,473.0/
      DATA STTF/280.2,279.5,277.9,275.3,272.0,268.8,265.5,262.3,259.0
     2           ,255.8,252.5,249.3/

2     FORMAT(1X,19H NO DATA FOR TFIRE=,F7.1)
3     FORMAT(1H1)
4     FORMAT(8F10.2)
5     FORMAT(10X,3F10.2)
    6 FORMAT(2X,12F10.2)
    7 FORMAT(1H )
    8 FORMAT(2X,7F10.2)
10    FORMAT (13A6,A2)
12    FORMAT(/65H        LATITUDE       LONGITUDE
```

```
     1          ./,2F15.2)
13       FORMAT(/15X,9HNORTHING=,D20.8,18H            EASTING=,D20.8)
30       FORMAT(1X,I2,F7.2,F10.2,F5.2,I5,12X,F8.2,F10.2,F5.2,I5)
42       FORMAT(5X,2I5,2F10.2,2I10)
 43      FORMAT(5X,3I5)
 44      FORMAT(5X,I5,I10,F10.2)
 45      FORMAT(5X,3I10)

         PRINT 3
         PRINT 1100
         PRINT 3

C        THE NEXT DATA SET IS INPUT READ FROM DATA CARDS (VARIABLES ARE
C        DESCRIBED IN COMMENT CARDS THAT FOLLOW

         DEFT=7.5
         READ(5,10) ABCDEF
         WRITE(6,10) ABCDEF
         READ(5,30) IQ,XFIRE,XUL,XD,NX,YFIRE,YUL,YD,NY
         WRITE(6,30) IQ,XFIRE,XUL,XD,NX,YFIRE,YUL,YD,NY
         PRINT 1002
         READ(5,10) GHIJKL
         READ(5,42)NT,NL,TFCST,TFIRE,IDATE,JSTAT
         PRINT 1002
         PRINT 1002
         WRITE(6,1005)
         PRINT 1002
         READ(5,10) MNOPQR
         WRITE(6,10) MNOPQR
         READ(5,5)(XS(J),YS(J),ES(J),J=1,JSTAT)
         PRINT 5,(XS(J),YS(J),ES(J),J=1,JSTAT)
         NEF=0

C        THE FCST DATE (JDATE) AND TIME (JTIME) OF GWC DATA IS NOW READ IN

         PRINT 3
         READ(1) JDATE,JTIME,NT
         PRINT45,JDATE,JTIME,NT
         XTIME=FLOAT(JTIME)*0.01
         ITS1=1
         TLATE=TFIRE-1.0
         WRITE(6,10)GHIJKL
         WRITE(6,42)NT,NL,TFCST,TFIRE,IDATE,JSTAT

C        ABCDEF=HEADER LABEL CARD FOR FOLLOWING DATA
C        IQ=INDICATOR SHOWING HOW FINAL DATA IS TO BE PRINTED
C        1 PRINTS HARD COPY OF CURVES AND DATA FOR CURVES
C        -1 PRINTS DATA FOR CURVES ONLY

C        XFIRE=LONGITUDE OF CENTER OF FIRING PATH (DEGREES AND TENTHS)
C        XUL=LONGITUDE OF UPPER LEFT HAND CORNER OF GRID
C        XD=DISTANCE (DEGREES AND TENTHS) BETWEEN GRID POINTS IN X (LONG.)
C        NX=NUMBER OF MINI GRID ARRAY POINTS IN X DIRECTION (LONGITUDE)
C        YFIRE=LATITUDE OF CENTER OF FIRING PATH (DEGREES AND TENTHS)
C        YUL=LATITUDE OF UPPER LEFT HAND CORNER OF GRID
```

```
C      YD=DISTANCE IN DEG. AND TENTHS BETWEEN GRID POINTS IN Y DIR. (LAT)
C      NY=NUMBER OF MINI GRID ARRAY POINTS IN Y DIRECTION (LATITUDE)
C      GHIJKL=HEADER LABEL CARD FOR FOLLOWING DATA
C      NT=NUMBER OF 1 HR FCST ARRAY PERIODS INCLUDING TIME OF FCST
C      NL=NUMBER OF LEVELS
C      TFCST=GMT TIME OF FIRST ARRAY OF UPDATED GWC FORECAST
C      TFIRE=GMT TIME OF FIRING (HRS AND MIN)
C      IDATE=DATE OF GWC FORECAST
C      JSTAT=NUMBER OF OBSERVATION STATIONS
C      XS(J)=LONGITUDE OF REPORTING STATION IN DEG AND HNDTHS
C      YS(J)=LATITUDE OF REPORTING STATION IN DEG AND HNDTHS
C      ES(J)=ELEVATION OF REPORTING STATION IN METERS

       IY=INT(IDATE*0.0001)
       IM=INT(IDATE*0.01)-IY*100
       ID=IDATE-IY*10000-IM*100
       IH=INT(TLATE)
       IMN=(TLATE-IH)*60
       IMDATE=IMN+60*(IH+24*(ID+IMD(IM)+365*IY-366))-IBCK
       REX=0.0
       REX1=0.0
       XEND=TFCST+NT-1
       CALL TIME (TFIRE,TFCST,TTS,TL,ITS,ITL,XEND,REX1)
       IF (REX1.EQ.59) GO TO 600
       CALL CENTER(XFIRE,YFIRE,XUL,YUL,XD,YD,NX,NY,PN,PE,PPS,PW,
      1IPN,IPE,IPS,IPW,REX)
       IF (REX.EQ.71) GO TO 600
       ITSS=ITS-1
       IF(JDATE.NE.IDATE)PRINT 1001
       IF(XTIME.NE.TFCST) PRINT 1001
       IF(JDATE.NE.IDATE)GO TO 600
       IF (TFIRE.GT.XEND.OR.TFIRE.LT.TFCST) PRINT2,TFIRE

C      THE GWC FCST DATA IS SCANNED AS (DUM) TO DETERMINE THE FCST DATA
C      ON EACH SIDE OF THE TIME OF FIRING

       IF(ITSS.LT.ITS1) GO TO 202
   198 DO 200 JT=ITS1,ITSS
       DO 200 JL=L1,L4
200    READ(1)IUM

C      IN THE 211,210 DO LOOPS, THE GWC FCST DATA FOR LEVELS L1 TO L4 IS
C      NOW READ FOR THE FCST TIME ON EACH SIDE OF THE TIME OF FIRING

202    ITS1=ITSS+3
       PRINT 43,ITSS,ITS1,JT
       DO 211 JT=1,2
       DO 210 JL=L1,L4
       READ(1) ((U1(J,I),V1(J,I),H1(J,I),I=1,I7),J=1,J7)
       DO 205 I=1,I7
       DO 205 J=1,J7
       IH1=INT(H1(J,I)*0.0001)
       T1(J,I)=IABS(H1(J,I)-IH1*10000)
       H1(J,I)=IH1
205        CONTINUE
```

```
      DO 209 JX=1,I7
      DO 208 JY=1,J7
      JXY=JX+(JY-1)*NX
      HH(JXY,JL,JT)=H1(JY,JX)*0.1
      TV(JXY,JL,JT)=T1(JY,JX)*0.1
      U(JXY,JL,JT)=U1(JY,JX)*0.1
208   V(JXY,JL,JT)=V1(JY,JX)*0.1
209   CONTINUE
210   CONTINUE
211   CONTINUE
      JX=IPW
      JY=IPS
      JXY=JX+(JY-1)*NX
      JWS=JXY
      JX=IPE
      JXY=JX+(JY-1)*NX
      JES=JXY
      JY=IPN
      JXY=JX+(JY-1)*NX
      JEN=JXY
      JX=IPW
      JXY=JX+(JY-1)*NX
      JWN=JXY
C     IN THE 250 DO LOOPS, HEIGHTS, TEMPERATURES, U AND V COMPONENTS FOR
C     THE VARIOUS LEVELS (JL=L1,L4) ARE COMPUTED FOR THE LOCATION
C     OF XFIRE AND YFIRE
      DO 250 JT=1,2
      DO 250 JL=L1,L4
      CALL INTERP(PW,PE,HH(JWS,JL,JT),HH(JES,JL,JT),XFIRE,
     1HHXFS)
      CALL INTERP(PW,PE,HH(JWN,JL,JT),HH(JEN,JL,JT),XFIRE,
     1HHXFN)
      CALL INTERP(PPS,PN,HHXFS,HHXFN,YFIRE,HHFIN)
      HHFNAL(JL,JT)=HHFIN
      CALL INTERP(PW,PE,TV(JWS,JL,JT),TV(JES,JL,JT),XFIRE,
     1TVXFS)
      CALL INTERP(PW,PE,TV(JWN,JL,JT),TV(JEN,JL,JT),XFIRE,
     1TVXFN)
      CALL INTERP(PPS,PN,TVXFS,TVXFN,YFIRE,TVFIN)
      TVFNAL(JL,JT)=TVFIN
      CALL INTERP(PW,PE,U(JWS,JL,JT),U(JES,JL,JT),XFIRE,UXFS)
      CALL INTERP(PW,PE,U(JWN,JL,JT),U(JEN,JL,JT),XFIRE,UXFN)
      CALL INTERP(PPS,PN,UXFS,UXFN,YFIRE,UFIN)
      UFINAL(JL,JT)=UFIN
      CALL INTERP(PW,PE,V(JWS,JL,JT),V(JES,JL,JT),XFIRE,VXFS)
      CALL INTERP(PW,PE,V(JWN,JL,JT),V(JEN,JL,JT),XFIRE,VXFN)
      CALL INTERP(PPS,PN,VXFS,VXFN,YFIRE,VFIN)
      VFINAL(JL,JT)=VFIN
250   CONTINUE
C     IN THE 260 DO LOOP, HEIGHTS, TEMPERATURES, U AND V COMPONENTS FOR
C     THE VARIOUS LEVELS (JL=L1,L4) AT LOCATION XFIRE,YFIRE ARE COMPUTED
C     FOR THE TIME OF FIRING (TFIRE)
```

```
      DO 260 JL=L1,L4
      CALL INTERP (TTS,TL,HHFNAL(JL,1),HHFNAL(JL,2),TFIRE,HHTF(JL))
      CALL INTERP (TTS,TL,TVFNAL(JL,1),TVFNAL(JL,2),TFIRE,TVTF(JL))
      CALL INTERP (TTS,TL,UFINAL(JL,1),UFINAL(JL,2),TFIRE,UTF(JL))
      CALL INTERP (TTS,TL,VFINAL(JL,1),VFINAL(JL,2),TFIRE,VTF(JL))
260   CONTINUE
      DO 435 LHT=L1,L4
      HHTFG(LHT)=HHTF(LHT)+STV(LHT)-ES(IA)
  435 CONTINUE
      WRITE(6,1045) JDATE,JTIME
      PRINT 1112,UTF
      PRINT 1112,VTF
      PRINT 1112,TVTF
      PRINT 1112,HHTFG

C     SOUNDINGS OF THE AVAILABLE U.S. ARMY RAWINSONDE STATIONS (ON TAPE)
C     ARE READ IN IN SUBROUTINE RAWIN

      I=1
      JT=JSTAT
      CALL RAWIN(I,JT,DIFSEC,ES,UZ,VZ,HZ,PZ,TZ,IMD,IMDATE,IDIF,IGMT)

C     IN DO LOOP 311, THE BEST AVAILABLE STATION IS LOCATED BASED ON THE
C     TIME AND LOCATION OF THE SOUNDINGS AVAILABLE

      DO 311 J=1,JT
      XLOD=(XS(J)-XFIRE)*111.137*COS(YFIRE*0.01745)
      YLAD=(YS(J)-YFIRE)*111.137
      CDIS(J)=ABS(DIFSEC(J))+.5*SQRT(XLOD*XLOD+YLAD*YLAD)
311   CONTINUE
      IA=1
      CMIN=1.E+06
      DO 320 J=1,JT
      IF(CDIS(J).GT.CMIN.OR.UR(9,J).LT.-200.0) GO TO 320
      CMIN=CDIS(J)
      IA=J
320   CONTINUE
      PRINT 42,IA

C     AT THIS POINT, THE CURVE OF THE BEST AVAILABLE SOUNDING IS
C     PRINTED AND THE CURVES ARE MAPPED FOR BOTH THE BEST AVAILABLE AND
C     THE UPDATED SCUNDING

      KQT=2
  389 DO 400 L=1,L12
      UF(L)=XNIL
      VF(L)=XNIL
      TF(L)=XNIL
      PF(L)=XNIL
      HF(L)=XNIL
      DO 390 J=1,JT
      US(J)=UR(L,J)
      VS(J)=VR(L,J)
      TS(J)=TR(L,J)
```

```
      HS(J)=HR(L,J)
      PS(J)=PR(L,J)
      IF (US(J).LT.-200.0) GO TO 390
      IF (PS(J).LT.100.0.OR.PS(J).GT.1000.0) PS(J)=STPF(L)
      IF (TS(J).LT.230.0.OR.TS(J).GT.300.0) TS(J)=STTF(L)+DEFT
  390 CONTINUE
      CALL BEST(KQT,JT,YS,XS,VS,US,PS,TS,YFIRE,XFIRE,
     2          VF(L),UF(L),PF(L),TF(L))
      HF(L)=STHF(L)
  393 IF (TF(L).LT.230.0.OR.TF(L).GT.300.0) TF(L)=STTF(L)+DEFT
      IF (PF(L).LT.100.0.OR.PF(L).GT.1000.0) PF(L)=STPF(L)
  394 IF      (UF(L) .GT.-200.0) GO TO 396
      IF (L.EQ.1) GO TO 395
      UF(L)=UF(L-1)
      VF(L)=VF(L-1)
      GO TO 400
  395 UF(L)=200.0
      VF(L)=200.0
      GO TO 400
  396 UF(L)=UF(L)+200.0
      VF(L)=VF(L)+200.0
 400  CONTINUE
      PFD(1)=PF(1)
      X(1)=XUL
      Y(1)=YUL
      DO 410 I=2,7
      X(I)=X(I-1)+XD
      Y(I)=Y(I-1)-YD
 410  CONTINUE
      DO 417 L=L1,L4
      UTF(L)=UTF(L)+200.0
  417 VTF(L)=VTF(L)+200.0
      CALL MOVCUR(UF,PF,UTF,PFD,XNDU)
      CALL MOVCUR(VF,PF,VTF,PFD,XNDV)
      DO 425 L=1,L12
      IF (UF(L).LT.-200.0) GO TO 425
      UF(L)=UF(L)-200.0
      VF(L)=VF(L)-200.0
      XNDU(L)=XNDU(L)-200.0
      XNDV(L)=XNDV(L)-200.0
  425 CONTINUE
      DO 427 L=L1,L4
      UTF(L)=UTF(L)-200.0
  427 VTF(L)=VTF(L)-200.0
      CALL MOVCUR(TF,PF,TVTF,PFD,XNDT)
      CALL MOVCUR(HF,PF,HHTFG,PFD,XNDH)
      IF(IQ.LT.1) GO TO 450
      XMAX=20.
      XMIN=-20.
      XLAB=6HU-COMP
      PRINT 1010
      CALL PNTDAT(UF,PF,XNDU,PF,IND,IND,XMAX,XMIN,YMAX,YMIN,BOB)
      XLAB=6HV-COMP
      PRINT 1011
      CALL PNTDAT(VF,PF,XNDV,PF,IND,IND,XMAX,XMIN,YMAX,YMIN,BOB)
```

```
      XMAX=310.
      XMIN=210.
      XLAB=6H TEMP
      PRINT 1012
      CALL PNTDAT(TF,PF,XNDT,PF,IND,IND,XMAX,XMIN,YMAX,YMIN,BOB)
      XMAX=16000.
      XMIN=0.0
      XLAB=6HHEIGHT
      PRINT 1013
      CALL PNTDAT(HF,PF,XNDH,PF,IND,IND,XMAX,XMIN,YMAX,YMIN,BOB)
  450 CONTINUE
      PRINT 6,(UF(L),L=1,12)
      PRINT 6,(VF(L),L=1,12)
      PRINT 6,(TF(L),L=1,12)
      PRINT 6,(HF(L),L=1,12)
      PRINT 6,(PF(L),L=1,12)
      PRINT 7
      PRINT 6,(XNDU(L),L=1,12)
      PRINT 6,(XNDV(L),L=1,12)
      PRINT 6,(XNDT(L),L=1,12)
      PRINT 6,(XNDH(L),L=1,12)
      IF(UF(1).EQ.0.0.AND.VF(1).EQ.0.0) GO TO 460
      GO TO 500
460   IF(TF(1).EQ.0.0.AND.HF(1).EQ.0.0) PRINT 2,TFIRE
500   CONTINUE

C        WSTM CONVERSION

         RAD=0.0174532925
         YL=YFIRE*RAD
         XL=XFIRE*RAD
         CALL WSTM(YL,XL,XX,YY)
      PRINT 3
      PRINT 1046
      PRINT 1002
      PRINT 1040
      PRINT 1002
      PRINT 1020
      PRINT 1002
      PRINT 1025
      PRINT 1002

C     IN DO LOOP 470, DATA FOR BOTH THE BEST AVAILABLE SOUNDING AND
C     UPDATED SOUNDING ARE PRINTED (F.1 FORMAT) FOR ZONES, PRESSURE,
C     TEMPERATURE, AND U AND V COMPONENTS

      DO 470 ND=1,12
      IF (PF(ND).GT.0.0) GO TO 523
      TF(ND)=XNIL
      UF(ND)=XNIL
      VF(ND)=XNIL
      XNDT(ND)=XNIL
      XNDU(ND) =XNIL
      XNDV(ND) =XNIL
523   PRINT 1030, ND,PF(ND),TF(ND),UF(ND),VF(ND),ND,PF(ND),
```

```
     1XNDT(ND).XNDU(ND).XNDV(ND)
470    CONTINUE
       PRINT 1002
       PRINT 12, YFIRE,XFIRE
 472   CONTINUE
       PRINT 1050
       PRINT 1002
       PRINT 1060
       PRINT 1020
       PRINT 1070
       PRINT 1002
C      IN DO LOOP 480, DATA FOR BOTH THE BEST AVAILABLE SOUNDING AND
C      UPDATED SOUNDING ARE PRINTED IN COMPUTER MET MESSAGE FORMAT
       DO 480 ND=1,12
       IF(UF(ND).EQ.0.0.AND.VF(ND).EQ.0.0) GO TO 474
       DIR1=ATAN2(-UF(ND),-VF(ND))*180/3.14159
       IF (DIR1.LT.0.0) DIR1=DIR1+360
       XMILS1(ND)=DIR1*(6400.0/360.0)/10.0
       XMPS1=SQRT(UF(ND)*UF(ND)+VF(ND)*VF(ND))
       XNOTS1(ND)=1.94254*XMPS1
       GO TO 475
  474  XMILS1(ND)=0.0
       XNOTS1(ND)=0.0
475    IF(XNDU(ND).EQ.0.0.AND.XNDV(ND).EQ.0.0) GO TO 476
       DIR2=ATAN2(-XNDU(ND),-XNDV(ND))*180/3.14159
       IF (DIR2.LT.0.0) DIR2=DIR2+360
       XMILS2(ND)=DIR2*(6400.0/360.0)/10.0
       XMPS2=SQRT(XNDU(ND)*XNDU(ND)+XNDV(ND)*XNDV(ND))
       XNOTS2(ND)=1.94254*XMPS2
       GO TO 478
476    CONTINUE
478    N=ND-1
       IXNDT=IFIX(10.0*XNDT(ND)+.5)
       IPF=IFIX(PF(ND)+.5)
       IXMIL1=IFIX(XMILS1(ND)+.5)
       IXNOT1=IFIX(XNOTS1(ND)+.5)
       IXMIL2=IFIX(XMILS2(ND)+.5)
       IXNOT2=IFIX(XNOTS2(ND)+.5)
       ITF=IFIX(10.0*TF(ND)+0.5)
       IF (PF(ND).GT.0.0) GO TO 533
       ITF   =NIL
       IXNDT=NIL
       IXNOT1=NIL
       IXNOT2=NIL
       IXMIL1=NIL
       IXMIL2=NIL
533    PRINT 1080,N,IPF,ITF,IXMIL1,IXNOT1,N,IPF,IXNDT,IXMIL2,IXNOT2
       WRITE (3,1082)
      1          NAR,N,IPF,ITF,IXMIL1,IXNOT1,N,IPF,IXNDT,IXMIL2,IXNOT2
480    CONTINUE
C      PRINT 13,YY,XX
C
       ITS2=ITS1
```

```
      IF (ITS2.GT.NT) GO TO 550
      DO 540 JT=ITS2.NT
      DO 540 JL=L1,L4
  540 READ (1) IUM
  550 CONTINUE
      END FILE 3
 1001 FORMAT(1X,46HDATE TIME OF GWC FCST DIFFERENT THAN DATA CARD)
 1002 FORMAT(1X,2I15)
 1005 FORMAT(17X,17HARMY STATION DATA)
 1010 FORMAT(1H1,15X,46HPRINTOUT OF GRAPHICAL DATA (X=U COMP, Y=PRESS)/)
 1011 FORMAT(1H1,15X,46HPRINTOUT OF GRAPHICAL DATA (X=V COMP, Y=PRESS)/)
 1012 FORMAT(1H1,15X,44HPRINTOUT OF GRAPHICAL DATA (X=TEMP, Y=PRESS)/)
 1013 FORMAT(1H1,15X,46HPRINTOUT OF GRAPHICAL DATA (X=HEIGHT, Y=PRESS)/)
 1020 FORMAT(4X,23HBEST AVAILABLE SOUNDING,20X,16HUPDATED SOUNDING)
 1025 FORMAT(1X,70HZONE   PRESS   TEMP   UCOMP   VCOMP        ZONE   PRESS   TE
     1MP   UCOMP   VCOMP)
 1030 FORMAT(2X,I3,F7.1,F6.1,2F7.1,I11,F7.1,F6.1,2F7.1)
 1031 FORMAT(//10X,5HCMIN=,F10.2,10X,3HIA=,I5)
 1040 FORMAT(7X,49HPRESS IN MBS, TEMP IN DEG(K), U AND V COMP IN MPS)
 1045 FORMAT(10X,10HGWC DATE =,I10,10X,10HGWC TIME =,I10)
 1046 FORMAT(16X,15HSTANDARD FORMAT)
 1050 FORMAT(21X,27HCOMPUTER MET MESSAGE FORMAT)
 1060 FORMAT(1X,79HPRESS IN MBS, TEMP IN TENTHS OF DEG(K), DIRECTION IN
     1TENS OF MILS, SPEED IN KTS)
 1070 FORMAT(1X,70HZONE   PRESS   TEMP   DIR   SPEED        ZONE   PRESS   TE
     1MP   DIR   SPEED )
 1080 FORMAT(2X,I3,I7,I6,2I7,I11,I7,I6,2I7)
 1082 FORMAT(2X,11I7)
 1100 FORMAT(///47X,30HARTILLERY APPLICATIONS ROUTINE,    //////
     2///,    57X,5HUNITS,///,53X,11HSPEED - MPS,//,53X,15HDIRECTION - DE
     3G,//,   53X,15HHEIGHT - METERS,//,53X,19HTEMPERATURE - DEG K)
 1110 FORMAT(6X,8HGWC DATA/)
 1112 FORMAT(4X,5E12.3)
  600 STOP
      END
```

```
      SUBROUTINE  RAWIN(I,JT,TS,ES,UR,VR,HR,PR,TR,IMD,IDATE,IDIF,IGMT)
C THIS SUBROUTINE READS IN THE U.S.ARMY RAWINSUNDE DATA.
C AUG 1977 VERSION: - MODIFIED TO SELECT DATA TYPES IT=1 OR 2 ONLY, AND
C  TO INTERPOLATE AND EXTRAPOLATE WHEN WIND PROFILES ARE INCOMPLETE.
C
      DIMENSION IR(144)
      DIMENSION  UR(1),VR(1),HR(1),TR(1),PR(1),ES(1),TS(1),IMD(1)
      DIMENSION  DAT(512),IS(25),HOZ(17)
      DATA ACR,CKM,XNIL/0.0174533,0.5148,-999.9/
      DATA J3,J10,J12,J17,J23,J28,J51/3,10,12,144,23,28,51/
      DATA  HOZ/0.0,100.0,350.0,750.0,1250.0,1750.0,2250.0,2750.0,3250.0
     2      ,3750.0,4250.0,4750.0,5500.0,6500.0,7500.0,8500.0,9500.0/
      SPDMX=100.0
      DO 18 L=1,JT
      TS(L)=XNIL
   18 IS(L)=11
      DO 19 L=1,J17
      IR(L)=0
      HR(L)=XNIL
      TR(L)=XNIL
      PR(L)=XNIL
      UR(L)=XNIL
   19 VR(L)=XNIL
      IFIL=0
      IF (I.GT.1) GO TO 22
C
C READS IN DATA SET
C
   20 READ (7)  DAT
      IF (EOF(7))124,21
  124 IFIL=IFIL+1
      IF (IFIL.GT.1) GO TO 32
      GO TO 20
C
C LOOP THROUGH DATA SET IN RECORD
C
   21 DO 30 J=1,J10
   22 JC=(J-1)*J51+1
C
C CHECKS DATA FOR DATE,TIME,AND TYPE
C
      IF (DAT(JC).LT.0.0) GO TO 30
      IP1=INT(DAT(JC)*1.0E-4)
      DATJ=DAT(JC)-IP1*1.0E4
      IP2=INT(DATJ*1.0E-2)
      DATJ=DATJ-IP2*1.0E2
      IP3=INT(DATJ)
      IP4=INT(DAT(JC+1)*0.01)
      IP5=DAT(JC+1)-IP4*100
      JDATE=IP5+60*(IP4+24*(IP3+IMD(IP2)+365*IP1-366))-IGMT
      IF (JDATE.LT.IDATE-IDIF) GO TO 30
      IF (JDATE.GT.IDATE+IDIF) GO TO 32
   24 JS=INT(DAT(JC+2)*0.1)
      IF (JS.LT.1.OR.JS.GT.JT) GO TO 30
      DAT2=DAT(JC+2)-JS*10
```

```
      IT=INT(DAT2)
      IF (IT.LT.1.OR.IT.GT.2) GO TO 30
      ESJS=ES(JS)
      TS(JS)=JDATE-IDATE
C SELECTS OUT PRESSURE,TEMPERATURES AND WINDS FOR ARTILLERY ZONES
      JCJ=JC+J28-2
      JX=JC+J3-1
      JKT=1
      DO 28 JH=1,J23,2
      JK=(JS-1)*J12+JKT
      JJH=JCJ+JH
      HR(JK)=HOZ(JKT)
      IF(ABS(DAT(JJH+1)).LE.SPDMX) GO TO 127
      IF (ABS(DAT(JJH-1)).GT.SPDMX.OR.JH.EQ.1) GO TO 27
      DAT(JJH+1)=DAT(JJH-1)$  DAT(JJH)=DAT(JJH-2)
      GO TO 128
  127 IR(JK)=1
      IF (ABS(DAT(JJH-1)).LE.SPDMX.OR.JH.EQ.1) GO TO 128
      DAT(JJH-1)=DAT(JJH+1)$  DAT(JJH-2)=DAT(JJH)
  128 ANG=ACR*DAT(JJH)
      IF (IT.GT.IS(JS).AND.IR(JK).EQ.1) GO TO 27
      UR(JK)=-DAT(JJH+1)*SIN(ANG)*CKM
      VR(JK)=-DAT(JJH+1)*COS(ANG)*CKM
   27 IF(DAT(JX+JH).LT.0.0) GO TO 28
      IF (IT.GT.IS(JS).AND.TR(JK).GT.0.0) GO TO 28
      PR(JK)=DAT(JX+JH)
      TR(JK)=DAT(JX+JH+1)+273.16
   28 JKT=JKT+1
      IF (IT.LT.IS(JS)) IS(JS)=IT
   30 CONTINUE
      GO TO 20
   32 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE BEST(KQT,JJ,YS,XS,VS,US,HS,TS,YL,XL,VL,UL,HL,TL)
C
C THIS SUBROUTINE CCMPUTES VALUES FROM OBSERVED DATA AND AN INITIAL
C  GUESS VALUE  (IF KQT= 2) BY A LEAST SQUARES FITTING OF THE DATA
C  (SEE ENDLICH AND MANCUSC, MON WEA REV. 1968, 342-350).
C
C THIS SUBROUTINE WAS ADDED TO THE AUG 1977 VERSION OF THE AAR PROGRAM.
C
C  JJ = NUMBER OF WIND DATA
C  KS = NUMBER OF CLOSEST DATA TO A USED TO COMPUTE ITS VALUE
C  W1 = WEIGHT GIVEN TO INITIAL GUESS VALUE
C  C2 = WEIGHTING CONSTANT
C
C  YS,XS = LATITUDE AND LONGITUDE OF WIND DATA (DEG)
C  US,VS = U AND V COMPONENTS OF WIND DATA (M SEC-1)
C  UN,VN(KQ=1) = INITIAL VALUE -- NOT USED
C              = FINAL VALUE --- A SMOOTH ANALYSIS USED AS THE INITIAL
C                                  VALUE IN THE KQ=2 COMPUTATION
C  UN,VN(KQ=2) = INITIAL VALUE --- USED AS THE INITIAL GUESS VALUE
C              = FINAL VALUE --- USED AS THE FINAL ANALYSIS
C  HS,HN = INITIAL DATA AND ANALYZED VALUE FOR AN ARBITRARY QUANTITY
C
      DIMENSION DVR(20)
      DIMENSION YS(1),XS(1),VS(1),US(1),HS(1),TS(1)
      COMMON/CPTS/   KS,W1,C2,RMAX,KSS5,IDS,KSW,ALPH
      EQUIVALENCE (DVR(1),DNH),(DVR(2),DHH),(DVR(3),DUH),(DVR(4),DVH),
     2  (DVR(5),DTH),(DVR(6),DXH),(DVR(7),DYH),(DVR(8),DXYH),
     3  (DVR(9),DXXH),(DVR(10),DYYH),(DVR(11),DXHH),(DVR(12),DXUH),
     4  (DVR(13),DXVH),(DVR(14),DYHH),(DVR(15),DYUH),(DVR(16),DYVH),
     5  (DVR(17),DXTH),(DVR(18),DYTH)
      ACR=3.1416/180.0
      KS=JJ
      DO 100 KQ=1,KQT
      KQ5=KQ-1+KS
      CM=COS(ACR*YL)
      K=0
      IF (KQ-1) 82,82,83
   82 NOD=0
      DO 182 IK=1,5
  182 DVR(IK)=0.0
      GO TO 84
   83 DO 183 IK=6,18
  183 DVR(IK)=0.0
      W=W1
      DNH=W
      NOD=1
      DHH=HL*W
      DUH=UL*W
      DVH=VL*W
      DTH=TL*W
   84 K=K+1
      IF (K-KS) 85,85,90
```

```
85 IF (NOD-KQ5)  86,90,90
86 J=K
   IF (ABS(US(J)).GT.100.0) GO TO 84
   XSJ=XS(J)
   YSJ=YS(J)
   USJ=US(J)
   VSJ=VS(J)
   HSJ=HS(J)
   TSJ=TS(J)
   DYS=YSJ-YL
   DXS= (XL-XSJ)*CM
   DYS2=DYS*DYS+DXS*DXS
   DXS2=0.5*DYS2
   IF (IDS.EQ.0) GO TO 385
   USK=USJ
   VSK=VSJ
   DXS1=USK*USK+VSK*VSK+0.01
   DXS2=(USK*DYS-VSK*DXS)
   DXS2=DXS2*DXS2/DXS1
385 W= C2/(DYS2+DXS2*ALPH+ C2)
   NOD=NOD+1
   DNH=DNH+W
   TSJ=TSJ*W
   HSJ=HSJ*W
   USJ=USJ*W
   VSJ=VSJ*W
   DHH=DHH+HSJ
   DUH=DUH+USJ
   DVH=DVH+VSJ
   DTH=DTH+TSJ
   IF (KQ-1) 84,84,89
89 DYH=DYH+DYS*W
   DXH=DXH+DXS*W
   DXYH=DXYH+DXS*DYS*W
   DXXH=DXXH+DXS*DXS*W
   DYYH=DYYH+DYS*DYS*W
   DXHH=DXHH+HSJ*DXS
   DYHH=DYHH+HSJ*DYS
   DXTH=DXTH+TSJ*DXS
   DYTH=DYTH+TSJ*DYS
   DXUH=DXUH+USJ*DXS
   DYUH=DYUH+USJ*DYS
   DXVH=DXVH+VSJ*DXS
   DYVH=DYVH+VSJ*DYS
   GO TO 84
90 CONTINUE
   IF (KQ-1) 92,92,94
92 IF (DNH) 110,110,93
93 DNH=1.0/DNH
   HL=DHH*DNH
   UL=DUH*DNH
   VL=DVH*DNH
   TL=DTH*DNH
   GO TO 100
94 IF (NOD-3) 110,95,95
```

```
 95 D=DYH*DYH-DNH*DYYH
    E=DXYH*DYH-DXH*DYYH
    A=DXH*DYH-DNH*DXYH
    B=DXXH*DYH-DXH*DXYH
    BDAE=B*D-A*E
    IF (BDAE) 97,110,97
 97 BI=1.0/BDAE
    C =DXHH*DYH-DHH*DXYH
    F =DYHH*DYH-DHH*DYYH
    CT=DXTH*DYH-DTH*DXYH
    FT=DYTH*DYH-DTH*DYYH
    CU=DXUH*DYH-DUH*DXYH
    FU=DYUH*DYH-DUH*DYYH
    CV=DXVH*DYH-DVH*DXYH
    FV=DYVH*DYH-DVH*DYYH
    HL=(B*F-C*E)*BI
    UL=(B*FU-CU*E)*BI
    VL=(B*FV-CV*E)*BI
    TL=(B*FT-CT*E)*BI
100 CONTINUE
110 CONTINUE
    RETURN
    END
```

Appendix C

LISTING OF RESULTS FOR INDIVIDUAL CASES

Appendix C

LISTING OF RESULTS FOR INDIVIDUAL CASES

LISTING OF THE DIFFERENCES BETWEEN ACTUAL AND SIMULATED IMPACT LOCATIONS SHOWN IN FIGURE 5

YEAR 1974		FIGURE 5A		FIGURE 5B		FIGURE 5C		FIGURE 5D	
DATE	TIME	DELTA-R	DELTA-D	DELTA-R	DELTA-D	DELTA-R	DELTA-D	DELTA-R	DELTA-D
1108	2100	64m	4m	416m	36m	222m	-13m	224m	-26m
1108	2200	-1	9	330	49	156	-5	156	-18
1108	2313	34	24	369	73	188	21	187	8
1108	2406	-15	24	266	91	74	32	71	17
1111	1307	-91	51	-112	103	-205	-42	-237	-33
1111	1400	-79	62	-95	115	-167	13	-193	20
1111	1500	-84	70	-79	107	-154	32	-181	35
1112	1330	-59	84	-58	117	-160	154	-152	125
1112	1430	-76	17	-76	57	-170	109	-170	72
1114	1300	27	42	86	111	-119	96	-63	50
1114	1400	35	44	94	105	-116	96	-63	48
1114	1500	-3	55	67	103	-238	101	-179	62
1114	1600	0	22	64	77	-203	77	-167	46
1114	1700	-65	8	-13	71	-267	78	-233	51
1114	1800	6	16	69	81	-162	86	-133	63
1114	1900	-68	10	36	91	-186	99	-150	76
1115	1317	41	6	279	85	209	36	198	15
1115	1415	-1	30	231	116	152	66	144	39
1115	1515	-6	46	277	159	173	101	159	76
1115	1615	14	41	243	121	134	70	121	45
1115	1715	-20	18	229	124	102	67	94	40
1115	1828	-13	23	240	132	96	69	91	44
1115	1915	-9	28	247	143	93	78	89	55
1118	1330	11	11	379	80	154	23	162	16
1118	1430	39	48	370	111	143	54	150	44
1118	1530	-2	48	324	109	86	53	91	40
1119	1330	-102	86	63	235	-97	147	-97	157
1119	1530	-13	37	148	169	-4	85	-15	88
1119	1630	4	-6	159	117	15	40	-0	39
1120	2002	26	0	323	-5	23	30	41	-21
1120	2100	-6	16	276	13	-49	35	-36	-12
1120	2200	16	-17	275	-18	-50	-6	-32	-50
1120	2300	-15	43	255	38	-80	41	-60	-3
1123	1431	-36	77	126	210	15	141	-15	137
1123	1530	-22	1	165	153	21	103	-6	95
1123	1630	-38	15	133	116	-3	76	-28	64

YEAR 1974		FIGURE 5A		FIGURE 5B		FIGURE 5C		FIGURE 5D	
DATE	TIME	DELTA-R	DELTA-D	DELTA-R	DELTA-D	DELTA-R	DELTA-D	DELTA-R	DELTA-D
1123	1732	-32	-24	131	81	15	49	-10	35
1123	1830	-52	4	41	85	-43	61	-72	43
1123	1930	-84	-20	-32	54	-109	32	-141	10
1123	2030	-25	15	-5	85	-63	68	-95	43
1123	2132	-57	1	-99	79	-128	70	-171	41
1126	2032	-66	-13	-24	76	-178	11	-176	-15
1126	2135	-63	12	-5	100	-148	31	-145	5
1126	2225	-78	8	-20	79	-166	21	-161	-4
1126	2330	-60	-29	8	34	-134	-18	-128	-44
1127	1730	-4	-43	276	-42	74	-64	57	-90
1127	1835	-9	-36	278	-29	77	-56	63	-77
1127	1930	5	-20	295	-9	96	-37	81	-57
1127	2030	-4	-8	303	13	102	-16	85	-37
1202	1332	-46	49	114	96	-125	84	-90	57
1202	1432	-21	63	104	107	-166	115	-106	77
1202	1530	-12	81	139	117	-173	140	-114	94
1202	1630	-46	33	95	81	-207	127	-151	73
1202	1734	-48	26	74	62	-211	120	-165	63
1202	183	-33	48	136	109	-116	172	-78	118
1202	1932	-24	31	129	87	-79	153	-45	101
1202	2030	-44	31	127	97	-53	163	-26	114
1203	1400	-38	0	72	41	-23	-3	-21	-12
1203	1500	-55	13	87	55	-76	13	-72	2
1203	1600	-33	14	106	51	-64	10	-56	-1
1203	1700	-44	6	117	46	-64	6	-56	-5

LISTING OF THE DIFFERENCES BETWEEN ACTUAL AND SIMULATED IMPACT LOCATIONS SHOWN IN FIGURE 6

YEAR 1974		FIGURE 6A		FIGURE 6B		FIGURE 6C		FIGURE 6D	
DATE	TIME	DELTA-R	DELTA-D	DELTA-R	DELTA-D	DELTA-R	DELTA-D	DELTA-R	DELTA-D
1108	2100	64m	4m	66m	12m	14m	12m	101m	-5m
1108	2200	-1	8	4	8	-19	12	68	-2
1108	2313	34	24	38	25	78	23	78	23
1108	2406	-15	24	-30	21	-49	28	-5	17
1111	1307	-91	51	-95	59	-42	49	-108	45
1111	1400	-79	62	-82	61	-78	62	-87	86
1111	1500	-84	70	-94	80	-56	52	-68	80
1112	1330	-59	84	-48	82	-79	88	-37	81
1112	1430	-76	17	-64	25	-87	3	-90	29
1114	1300	27	42	27	37	17	42	30	54
1114	1400	35	44	39	44	51	42	25	50
1114	1500	-3	55	-6	50	-11	56	15	48
1114	1600	0	22	3	22	6	15	-13	35
1114	1700	-65	8	-61	11	-74	-3	-65	20
1114	1800	6	16	28	14	1	11	-20	25
1114	1900	-68	10	-47	13	-111	1	-39	22
1115	1317	41	6	48	0	16	11	74	8
1115	1415	-1	30	13	31	-27	19	28	37
1115	1515	-6	46	-6	40	-16	43	19	46
1115	1615	14	41	17	38	-31	31	10	36
1115	1715	-20	18	-22	11	-44	27	10	0
1115	1828	-13	23	-6	27	-43	16	30	19
1115	1915	-9	28	-0	35	-32	26	13	16
1118	1330	11	11	32	15	-14	5	47	14
1118	1430	39	48	47	51	-1	33	67	62
1118	1530	-2	48	8	49	-5	60	1	43
1119	1330	-102	86	-90	93	-186	82	-84	53
1119	1530	-13	37	5	39	-29	37	20	21
1119	1630	4	-6	18	-4	-18	1	44	-21
1120	2002	26	0	17	3	58	6	58	6
1120	2100	-6	16	5	20	-36	12	-32	22
1120	2200	16	-17	32	-15	-25	-19	7	-10
1120	2300	-15	43	-14	43	-26	42	3	39
1123	1431	-36	77	-49	72	-79	67	-3	42
1123	1530	-22	1	-18	6	-68	9	56	-24
1123	1630	-38	15	-34	13	-88	-12	5	13

YEAR 1974		FIGURE 6A		FIGURE 6B		FIGURE 6C		FIGURE 6D	
DATE	TIME	DELTA-R	DELTA-D	DELTA-R	DELTA-D	DELTA-R	DELTA-D	DELTA-R	DELTA-D
1123	1732	-32	-24	-40	-23	-31	-33	-89	-45
1123	1830	-52	4	-63	-1	-41	2	-75	-2
1123	1930	-84	-20	-69	-27	-120	-41	-72	-47
1123	2030	-25	15	5	11	-8	1	-34	25
1123	2132	-57	1	-33	-4	-91	-1	-45	12
1126	2032	-66	-13	-54	-7	-66	-27	-54	-11
1126	2135	-63	12	-56	15	-155	27	-63	7
1126	2225	-78	8	-74	9	-65	1	-74	12
1126	2330	-60	-29	-46	-27	-81	-33	-37	-31
1127	1730	-4	-43	10	-41	-34	-47	39	-43
1127	1835	-9	-36	-6	-34	-27	-34	28	-34
1127	1930	5	-20	14	-18	-45	-28	46	-17
1127	2030	-4	-8	4	-8	-49	-7	14	-21
1202	1332	-46	49	-36	54	-62	30	-52	68
1202	1432	-21	63	-13	63	-51	58	37	66
1202	1530	-12	81	-2	74	-31	77	21	79
1202	1630	-46	33	-33	30	-80	43	7	12
1202	1734	-48	26	-41	24	-63	29	-34	9
1202	1830	-33	48	-25	51	-73	47	8	44
1202	1932	-24	31	-18	32	-49	21	-9	18
1202	2030	-44	31	-42	37	-64	30	-14	19
1203	1400	-38	0	-21	-3	-89	-6	58	41
1203	1500	-55	13	-37	12	-80	15	-0	5
1203	1600	-33	14	-24	14	-75	9	5	13
1203	1700	-44	6	-39	6	-81	10	18	9

LISTING OF THE DIFFERENCES BETWEEN ACTUAL AND SIMULATED IMPACT LOCATIONS SHOWN IN FIGURE 10

YEAR 1974		FIGURE 10A		FIGURE 10B		FIGURE 10C		FIGURE 10D	
DATE	TIME	DELTA-R	DELTA-D	DELTA-R	DELTA-D	DELTA-R	DELTA-D	DELTA-R	DELTA-D
1108	2100	-4m	-6m			-2m	-6m		
1108	2200	43	5	-54m	7m	37	6	-67m	6m
1108	2313	27	24	66	32	23	25	54	32
1108	2406	-26	53	-42	44	-22	52	-43	44
1111	1307	-52	39			-39	31		
1111	1400	-134	67	-53	53	-133	61	-36	41
1111	1500	-143	44	-107	61	-135	37	-106	55
1112	1330	-62	87			-70	95		
1112	1430	-49	18	-68	18	-64	20	-88	35
1114	1300	22	52			28	52		
1114	1400	27	31	21	48	39	31	35	44
1114	1500	-40	52	-18	19	-30	53	-1	37
1114	1600	-48	38	-46	23	-16	32	-31	22
1114	1700	-83	19	-149	40	-82	26	-94	28
1114	1800	37	16	-11	34	21	26	1	35
1114	1900	-48	32	-4	16	-38	32	-9	33
1115	1317	37	14			41	13		
1115	1415	-15	29	-14	45	-7	35	-7	44
1115	1515	25	83	0	64	26	77	15	72
1115	1615	25	35	24	57	14	24	37	47
1115	1715	-13	48	-9	41	-19	39	-16	23
1115	1828	-8	11	2	53	-9	12	-8	48
1115	1915	26	43	15	23	22	41	15	22
1118	1330	36	21			62	24		
1118	1430	12	41	29	49	3	43	58	56
1118	1530	10	54	-35	38	4	52	-47	39
1119	1330	-142	47			-152	47		
1119	1530	-5	4	-14	7	-6	7	-41	7
1119	1630	-10	-4	-3	-49	-10	-7	-8	-42
1120	2002	19	12			22	10		
1120	2100	32	21	36	31	25	21	19	28
1120	2200	2	-10	40	-9	-1	-8	29	-10
1120	2300	13	43	-18	45	9	41	-21	47
1123	1431	-86	26			-96	20		
1123	1530	-3	16	-55	-25	-1	10	-68	-33
1123	1630	-5	-27	-22	-20	-6	-37	-19	-27

YEAR 1974		FIGURE 10A		FIGURE 10B		FIGURE 10C		FIGURE 10D	
DATE	TIME	DELTA-R	DELTA-D	DELTA-R	DELTA-D	DELTA-R	DELTA-D	DELTA-R	DELTA-D
1123	1732	-38	-20	-22	-62	-60	-26	-21	-74
1123	1830	-125	-30	-129	-15	-126	-32	-150	-20
1123	1930	-152	-27	-222	-67	-170	-37	-223	-70
1123	2030	-16	-3	-105	2	-24	-5	-127	-8
1123	2132	-120	18	-105	-8	-130	16	-112	-9
1126	2032	-60	-19			-63	-20		
1126	2135	-71	11	-52	-10	-71	6	-58	-10
1126	2225	-52	-11	-74	-5	-63	-11	-79	-12
1126	2330	-58	-31	-19	-57	-65	-34	-39	-56
1127	1730	7	-33			12	-28		
1127	1835	50	-25	47	-20	63	-26	45	-12
1127	1930	13	-17	63	-5	12	-15	83	-4
1127	2030	68	6	40	6	50	5	35	10
1202	1332	-41	37			-27	36		
1202	1432	-53	64	-44	48	-52	70	-30	46
1202	1530	27	65	-17	71	31	66	-25	79
1202	1630	-48	39	-20	24	-50	40	-13	30
1202	1734	-57	7	-60	14	-48	3	-73	21
1202	1830	25	69	18	53	14	65	7	49
1202	1932	-9	25	46	44	-19	22	16	44
1202	2030	5	41	26	40	-8	40	-12	32
1203	1400	-13	-15			-16	-13		
1203	1500	-1	9	-17	-7	-2	16	-16	1
1203	1600	-21	2	28	1	-29	5	19	12
1203	1700	3	7	-7	-6	-5	9	-19	1

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